AIEE South West District Meeting, St. Louis, Mo., October 8–10, 1941

Electrical Engineering

September
1941

An Instrument That Gives You a Month's Operation on a 30-inch Chart

WHEN analyzing load or voltage surveys, it is no longer necessary to reel off 60 ft of strip chart, or to examine a number of round charts. This new instrument gives you a 30-day operating record on a 30-in. chart—thus you can quickly check current or voltage conditions for an entire month, or for any 24-hr period.

A 4-day record can be seen through the glass window. This makes it possible to check the record without opening the instrument and unrolling the chart.

IT'S INKLESS—REQUIRES NO ATTENTION

This new instrument is an addition to our proved Type CF line of inkless recorders. It is the inkless feature that makes possible the one-inch-per-day chart speed. At such a low speed, an ink recorder would form pools of ink that would blot out the record.

The inkless feature also enables the instrument to operate for a month without any attention, because the old troubles of pen clogging and ink freezing or evaporating are eliminated. Accurate in extremes of temperature—from −10 F to 120 F.

This instrument will be a worth-while addition to your testing equipment and should soon pay for itself in the time it saves. Bulletin GEA-3187 gives complete information. General Electric Company, Schenectady, N. Y.

HEADQUARTERS for ELECTRICAL MEASUREMENT

GENERAL ELECTRIC

Winding Wire Sample on Tester

A specimen of magnet wire is wound, under fixed tension, on the mandrel of the Tester.

Softness Reading on Indexed Dial

After the tension on specimen is released, re-coil of wire gives direct reading of "softness."

Increase your production with soft wire . . .
Check all incoming wire shipments this easy way

Hard magnet wire is springy. It refuses to fit readily into coil forms or slots. Its troublesome springiness slows up winding operations, because extra time is needed to make hard wire conform to the desired shapes of the windings.

Also, since hard wire is more difficult to manage than "dead soft" wire, it usually receives strenuous handling during winding operations. Damages to insulation are likely to occur, and more frequent coil failures are inevitable.

The combination of winding delays and frequent coil failures will slow up your production schedules. These troubles can be avoided if you keep hard wire out of your winding department.

A simple softness tester has been devised by Belden engineers which quickly detects hard wire. This tester, shown in use in the accompanying pictures, is available to all magnet wire users. It will test bare, enameled, and textile-insulated copper wire from No. 14 to No. 30 A.W.G. and give a direct scale reading of "softness."

The Belden Softness Tester does away with all guesswork regarding the softness of incoming wire shipments. It instantly shows up hard wire before it gets to your winders. It speeds up production and thus assures lowest over-all winding costs.

We shall be glad to send complete information on the Belden Softness Tester and explain its indexed dials.

Belden
MANUFACTURING COMPANY
4635 W Van Buren St., Chicago

Manufacturers of
Beldenamel • Silkenamel • Cotenamel
Glass-enamel • Celenamel • and Formvar

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices, 33 West 39th Street, New York, N. Y. Subscription $12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain and Spanish colonies, $13 to Canada; $14 elsewhere; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P.L. & R. Act of February 28, 1925.
September 1941, Vol. 60, No. 9. Number of copies this issue 22,500

WE'RE UP TO OUR EARS, TOO!

GENERAL RADIO COMPANY has refrained from advertising its contribution to the arming of the Country through supplying equipment for the Armed Forces for National Defense. We have accepted the added strain upon our manufacturing facilities as a patriotic duty to the country in which we plan and propose to be doing business for countless years to come; and we have felt little inclination to burden the readers of ELECTRICAL ENGINEERING with an account of the magnitude of our Defense business.

As manufacturers go, General Radio is a small organization. In normal times we have been able to produce instruments in sufficient quantity to take care of the requirements of Industry. In these emergency times, the volume of orders received from the Government plus the priority orders from subcontractors has sorely taxed our facilities. We have expanded in personnel and output to the limit of our physical structure.

As a result, without a priority preference rating it is sometimes difficult for us to fill orders, even for stock catalog items. How long this condition will continue, no one knows.

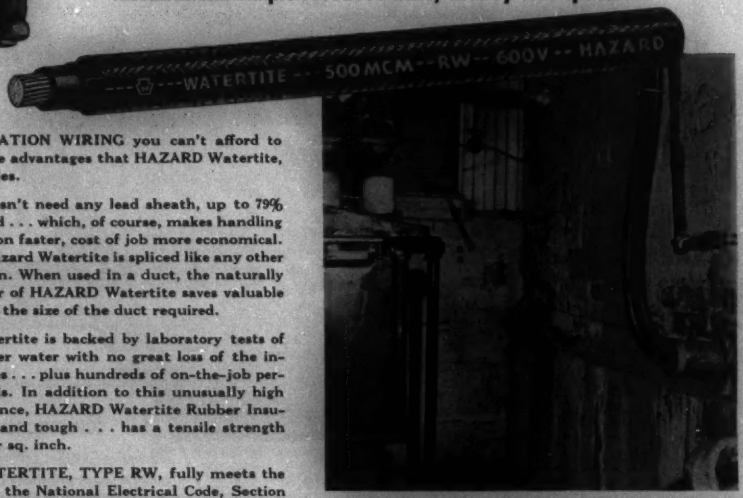
We ask the forbearance of our thousands of long-time friends. We assure them that our engineering staff is intact and busier than ever in developing devices and techniques for National Defense projects, which will benefit users of General Radio instruments in the future. Many new instruments have been brought up to the point of manufacture. New instruments will be developed constantly. At the very first sign of return to normal times these instruments will be available in quantity, immediately.

We do propose, however, in future advertisements in this magazine to do a thing we have been wanting to do for a long time . . . . . we propose to take you into General Radio's plant as far as Government regulations will allow . . . . to describe a number of unique methods of design, manufacture and calibration which, we believe, contribute in no small measure to our long-standing position in the instrumentation field.

We shall try to make these advertisements of sufficient value to hold your interest. We will welcome your comments.

GENERAL RADIO COMPANY, Cambridge, Massachusetts

HAZARD WATERTITE TYPE RW—for use instead of lead-sheathed wire in wet locations...eliminates lead wipes...makes installations simple...saves time, money and space.



Typical use of Hazard Watertite, Type RW, in a wet location. 3 1/C 500,000 CM Hazard Watertite, 220 volts, used from transformer bank through building wall and underground in pipe to next building in manufacturing plant.

FOR WET LOCATION WIRING you can't afford to overlook all these advantages that HAZARD Watertite, Type RW, provides.

Because it doesn't need any lead sheath, up to 79% in weight is saved . . . which, of course, makes handling easier, installation faster, cost of job more economical. What's more, Hazard Watertite is spliced like any other rubber insulation. When used in a duct, the naturally smaller diameter of HAZARD Watertite saves valuable space or reduces the size of the duct required.

HAZARD Watertite is backed by laboratory tests of seven years under water with no great loss of the insulating qualities . . . plus hundreds of on-the-job performance records. In addition to this unusually high moisture-resistance, HAZARD Watertite Rubber Insulation is strong and tough . . . has a tensile strength of over a ton per sq. inch.

HAZARD WATERTITE, TYPE RW, fully meets the requirements of the National Electrical Code, Section 3035, for wiring in wet locations.

See the Difference in Weight and Diameter!

	HAZARD Watertite Type RW Size 4/0	Lead Covered Type RL Size 4/0
Approx. O. D. Inches	.78	.84
Approx. Net Weight Per M Ft.	814 lbs.	1570 lbs.

HAZARD INSULATED WIRE WORKS
DIVISION OF THE OKONITE COMPANY
Works: Wilkes-Barre, Pennsylvania
Offices in Principal Cities

NOW POWER-LEVEL INSULATION IN A 15-KV C.T.

THIS G-E outdoor current transformer, Type JK-12, is adequately insulated—it passes the 110-kv, full-wave impulse-test requirement.

FOR BOTH METERING AND RELAYING

The 5- to 800-amp ratings of the Type JK-12 meet the highest-accuracy classification, ¼X, ¼Y, and ¼Z; the 1000- and 1200-amp ratings meet the ½X, ½Y, and ½Z classification. Its characteristics during overcurrent conditions make it particularly well suited for relaying as well as for metering. General Electric, Schenectady, N. Y.

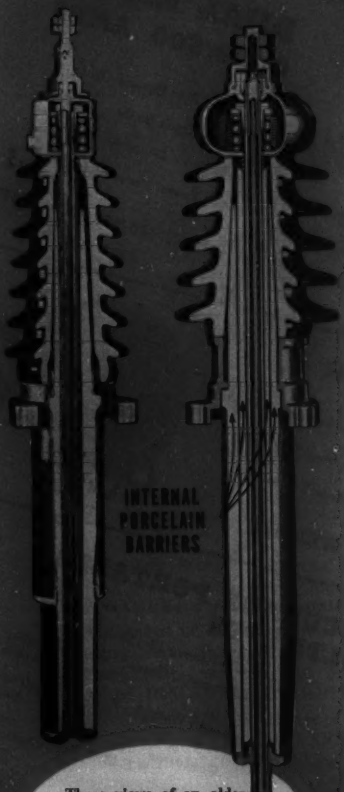
CONSTRUCTION

Mounting—either vertical or horizontal • Case—aluminum (rustproof and requires no paint) • Compound filling—high dielectric strength • Primary bushing—undercut skirts provide great creepage distance • Primary terminals—threaded-stud type • Secondary terminals—fixed studs in a compartment with conduit connections

GENERAL ELECTRIC

GREATER STABILITY MEANS

Less Bushing Worry



These views of an older Class L bushing (left) and a new unit with a quarter section removed show the greater use of internal porcelain in the latest design.

● Magic word—stability—for it signifies that a bushing's characteristics are not subject to change, and that the unit will give trouble-free service for years on end. Absolute stability is the dream of every bushing user, and O-B's new bushings are very close to this ideal. Various forms of voltage grading to prevent overstressing were used in previous designs but all of them restricted the use of porcelain. In the present bushings, a thin layer of conduction glaze aids in controlling overstress, and since it is surface-applied, thicker sections of porcelain can be used. Permitting greater and more effective use of internal porcelain, this feature adds to the dielectric stability. And the combination of better voltage grading and more porcelain increases the over-all electrical efficiency. In addition to this improvement, all of O-B's new bushings are completely and permanently sealed, a magnetic oil gauge is provided on Class G units, and transformer bushings have interchangeable terminals. To secure the several advantages of the greater stability and the other new features which have been added, be sure your bushing specifications call for O-B!

Buy the Best ... Buy O-B

Ohio Brass (B)

MANSFIELD, OHIO, U. S. A.

Canadian Ohio Brass Co., Ltd., Niagara Falls, Ont.

DELIVERIES—
NOT PROMISES!

LOW COST CLIPON AMMETER

..Perfect Balance
..Light Weight
..Completely Insulated Jaws
...±2% Accuracy

LIST $80.

DUAL RANGE 0-100/500 AMPS

..Large 2¼" Square Opening
..Long Open Scale
..80 Scale Divisions
..10 Years' Proven Service

ALSO MULTI RANGE CLIPON AMMETER 0-10/25/100/250/1000 AMPS.
LIST $120.

PHASE ROTATION INDICATOR

..Instant Indication of Phase Rotation
..110/550 Volts
..2½" Portable Pocket Model

LOW COST

..Complete with Heavy Insulated Leads
..Heavy Clips with Rubber Guards
..Also Flush and Surface Types

LIGHT WEIGHT

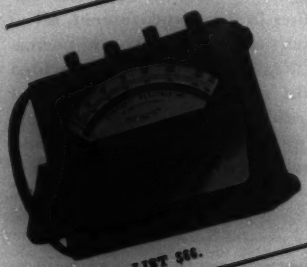
LIST $7

NEW HIGH ACCURACY PORTABLE VOLTMETER

..0-150/300/750 Volts
..Long 5¼" Scale
..½ of 1% Accuracy
..AC-DC
..Hand Calibrated Mirror Scale
..150 Scale Divisions

..Frequency 15-135 cps.
..Hinged Cover with Leather Carrying Handle
..Light Weight—Robust Construction
..Conforms to A.I.E.E. and N.E.M.A. Specifications

MADE IN U.S.A.



LIST $46.

NO DELAY

All Instruments Available Immediately from Stock

We can also give *immediate* deliveries on your requirements for Special Transformers, etc., etc.

FERRANTI ELECTRIC, INC.

30 Rockefeller Plaza
New York, N. Y.

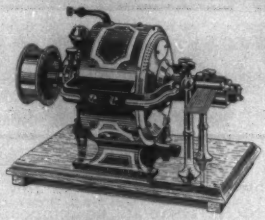
Ferranti Electric, Ltd., Toronto, Canada • Ferranti, Ltd., Hollinwood, England

TWO LEADERS

HANSON-VAN WINKLE-MUNNING CO. · MATAWAN, NEW JERSEY, U.S.A. · SINCE 1820

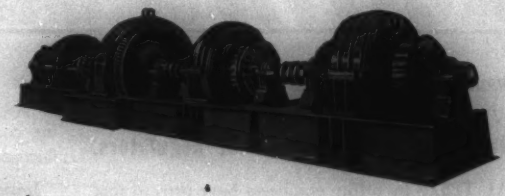
STANDARD OF THE WORLD
IRVINGTON INSULATION
TRADE MARK REG. U.S. PAT. OFF.

GET TOGETHER ON GENERATOR INSULATION



1876

The first recognized practical electro-plating generator. Built in 1876 by Hanson-Van Winkle-Munning Co. Now on display in Henry Ford Museum.



1941

Hanson-Van Winkle-Munning's modern long-life, high-efficiency Motor Generator Set.

Hanson-Van Winkle-Munning Company, leaders in the manufacture of electro-plating generators for 65 years, specify IRVINGTON and HARVEL INSULATING VARNISHES for perfect insulation in their generator armatures and fields.

Development of these Varnishes is the result of Irvington's 35 years' experience in meeting demands for insulating varnishes of the highest quality for dipping, brushing, spraying, vacuum and pressure applications. There's an IRVINGTON or HARVEL INSULATING VARNISH for every electrical need.

IRVINGTON VARNISHES are of the oxidizing type, containing drying oils; HARVEL 512-C and 612-C BAKING VARNISHES are phenol-aldehyde synthetic resins made from cashew nut shell liquid, solidifying throughout by heat induced chemical polymerization.

The IRVINGTON line consists of Clear and Black Baking Varnishes; Clear and Black Air Drying Varnishes; Black Insulating Paint; Black Air Drying, Baking and Flashing Core Plate Varnishes; Clear and Black Oilproof Finishing Varnishes; Clear Sticking Varnish; Red Oilproof Enamels, Gray and Black Machinery Enamels. In the HARVEL line are Baking and Air Drying Varnishes and Red Finishing Enamel.

For complete data send for the new 34-page HARVEL and IRVINGTON INSULATION VARNISH CATALOG. Write Dept. 36.

Irvington VARNISH & INSULATOR CO.

IRVINGTON, NEW JERSEY, U. S. A.

STANDARD OF THE WORLD
IRVINGTON INSULATION

PLANTS AT IRVINGTON, N. J. and HAMILTON, ONT., CAN.
Representatives in 20 Principal Cities

5/8% step regulators give you Narrow Band Widths WITHOUT 200% HIGHER EXCITING CURRENT!

Allis-Chalmers DFR Regulators Easily Hold 2-Volt Bands . . . Yet Need Only 1/3 the Exciting Current Required by Older Types of Regulators.

ACTUAL TESTS by utility engineers have proved that Allis-Chalmers 5/8% Step Regulators need *only 1/3 the exciting current required by older types of regulators!* Wattless current is cut 67% . . . more system capacity released for pay loads . . . fewer capacitors needed!

That's one reason why more and more systems are taking advantage of the savings of the Allis-Chalmers DFR — the only station-type step regulator for single-phase, 2400 and 4800 volt feeders on the market today. Here's another . . .

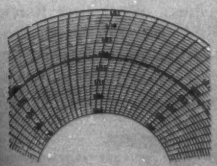
The Allis-Chalmers DFR Regulator easily holds narrow band widths — as low as ±3/4 volts on some feeders. There are no compounding or holding coils . . . the relay is free to follow each voltage fluctuation without excessive damping.

Important, too, are DFR's reduced losses, quieter operation, and minimum maintenance costs — all new standards in feeder voltage regulation.

Why not let an engineer in the nearest Allis-Chalmers district office show you how the Allis-Chalmers 5/8% Step Regulator can bring better regulation at lower all-around cost to your system? Call him today. Or write direct to Allis-Chalmers, Milwaukee, for your copy of Bulletin B-6065. A 1408

On the lines of a southern utility—three 72 kva, 2400 volt Allis-Chalmers DFR's (foreground) and one 216 kva, 4160 volt 5/8% Step AFR Regulator.

5/8% STEP REGULATORS Have Been Holding 2-VOLT BANDS FOR 7 YEARS!



When the Allis-Chalmers 5/8% Step Regulator was designed over eight years ago, the size of steps was selected as 5/8 of 1% because data gathered from utilities all over the country indicated that the 2-volt band was desirable.

A look at the accompanying chart —the actual record during operation on the lines of an eastern system — will show you how the Allis-Chalmers DFR *easily* holds a 2-volt band.

These 5/8% Step Regulators Are Famous for Better Regulation at Lower Cost! Choose the Regulator to Fit Your Purpose!

DFR — 12 to 250 kva, single phase
AFR — 20.8 to 750 kva, three phase
CFR (air cooled) — 36.96 kva, 2400 volt.

ALLIS-CHALMERS
MILWAUKEE-WISCONSIN

Electrical Engineering

Registered U. S. Patent Office

for September 1941—

The Cover: The equestrian statue of Saint Louis stands in front of the Art Museum in St. Louis, Mo., where the AIEE South West District meeting is to be held October 8–10, 1941 Photo courtesy St. Louis Chamber of Commerce

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VOLUME 60 FOUNDED 1884 NUMBER 9

A Monthly Publication of

American Institute of Electrical Engineers

33 West Thirty-Ninth Street, New York, N. Y.

DAVID C. PRINCE, President H. H. HENLINE, National Secretary

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¶ Statements and opinions given in articles and papers appearing in "Electrical Engineering" are the expressions of contributors, for which the Institute assumes no responsibility.

¶ Correspondence is invited on all controversial matters.

High Lights • •

Application of Interrupting Devices. The method of calculating system short-circuit currents developed by the AIEE subcommittee on circuit breakers, switches, and fuses consists of determining the highest value of symmetrical short-circuit current for any type of fault as obtained by dividing voltage by subtransient reactance, and assigning multiplying factors according to the basis of rating and speed of operation of the equipment concerned (*Transactions pages 877–81*). To facilitate the use of this method in the application of circuit breaker, the short-circuit ratings of breakers should be correlated so that a breaker selected for adequate interrupting capacity automatically has ratings adequate for other related requirements (*Transactions pages 882–4*).

Lightning Protection. The combination of overhead ground wires, transformer-mounted arresters, and line entrance gaps that has been found to provide effective protection from direct lightning strokes for high-voltage high-capacity stations usually is not economical for stations on sub-transmission systems where wood insulation is employed throughout; for these a high degree of protection can be achieved by the use of a reactor to compensate for the "turn-up" of the gap. (*Transactions pages 898–900*).

Fires of Electrical Origin. Between one-third and one-half of the fires of electrical origin reported to a large group of industrial fire-insurance companies are estimated to have been caused by poor maintenance of electrical equipment. With industrial production increasing at its present accelerated rate, under impetus of the National Defense Program, it is doubly important that this equipment be given the care that it merits, if a sharp increase in the proportion of electrical fires is to be averted (*pages 428–31*).

The Metering Art. The origins and progress to date of the art of metering electric energy have been made the subject of a historical survey undertaken under the direction of the AIEE committee on instruments and measurements. Ultimately to be published in pamphlet form, the report is being presented in four parts in this and subsequent issues of ELECTRICAL ENGINEERING; the first part deals with origins and pioneers (*pages 421–7*).

Insulation Testing. Nondestructive testing of insulation depends for success upon satisfactory correlation between dielectric strength and low-frequency interfacial polarization in insulation, which has been shown to exist because of their mutual dependence upon the abundance and disposition of free electrons and ions throughout the material (*Transactions pages 890–5*).

Industrial Network System. The industrial distribution system recently installed in an extension brought about by war-time expansion of a Canadian plant employs a development of the primary network principle rather than the conventional metropolitan type of network; functioning and cost of the two systems have been compared (*Transactions pages 862–5*).

Lightning Records. Oscillographic records of the wave shapes of natural lightning to the Empire State Building in New York, N. Y., were obtained in sufficient number during the summer of 1940 to make possible determination of frequency of occurrence of various rates of rise, crest currents, duration, and charge (*Transactions pages 885–90*).

Canadian Broadcasting. Under the control of the Canadian Broadcasting Corporation, which operates a nation-wide network in addition to its regulatory function, development of radiobroadcasting in Canada has been rapid; the system in practice is one of co-operation between a semipublic service and private ownership (*Transactions pages 896–8*).

Shielding Magnets. Forged steel magnets in watt-hour meters can be protected from the effects of transient magnetic fields by shielding with a thick copper coating applied by a new high-speed process; with this method of protection shielded and unshielded magnets are interchangeable (*Transactions pages 875–7*).

Oil for Circuit-Breaker Testing. Results of tests made by an AIEE working group to determine the minimum dielectric strength of oil for high-voltage circuit-breaker testing have been used as a basis for recommendations on the strength of oil for that purpose (*Transactions pages 903–06*).

Measuring Lightning Surges. The second of a series of three articles on lightning phenomena describes several special instruments that have been devised to secure for power-system engineers the information they must have to provide protection for the system (*pages 438–43*).

Branch Prize Paper. The AIEE national prize for Branch paper, for student papers presented during the year ending June 30, 1940, was awarded for a paper describing a stabilized neon-tube direct-coupled amplifier; an abstract appears in this issue (*page 437*).

Bus Protection. Standard high-speed directional and plunger-type relays of simple design provide the basis for a method of bus protection that requires neither matched current transformers nor insulation of all equipment from ground (*Transactions pages 859–62*).

Frequency Meter. Use of an iron-core cross-coil dynamometer eliminates the external reactor in a recently developed frequency meter. Compactness and lack of auxiliary equipment should make this instrument particularly valuable where space is limited (*Transactions pages 866–9*).

Life of Cold-Cathode Tubes. Experiments have proved that the life of cold-cathode tubes is determined solely by the current drawn. The establishment and application of a law of relationship between tube life and current drain are discussed (*Transactions pages 901–03*).

Mechanism of Air-Blast Breakers. Air-blast circuit breakers with voltage ranges from 4 to 230 kv have been described and the sequence of operations of three distinct types outlined in detail (*Transactions pages 869–74*).

Freon as an Insulating Medium. Tests have been made to see to what extent the chemical disintegration of Freon in the presence of corona and spark-over limits its use as a practical insulating medium for high-voltage equipment (*pages 435–6*).

High-Speed Radiography. With the recent development of a cold-cathode X-ray tube, radiographs can be made at speeds of about one microsecond, thus recording on film the distortion occurring inside objects opaque to visible light (*pages 432–5*).

Officers and Committees. National officers and committees chosen to serve the Institute during the year 1941–42 are listed in this issue; as are Section and Student Branch officers (*pages 453–7*).

Coming Soon. Among special articles and technical papers currently in preparation for early publication are: an article on developments in electric metering since 1900, the second part of the progress report sponsored by the AIEE committee on instruments and measurements; an article on field studies of lightning, the third and final part of the series on lightning phenomena by C. F. Wagner (F'40) and G. D. McCann (A'38); an article on styrene and its insulation potentialities by T. R. Scott; a paper on bushing tests by A. L. Brownlee (A'25) and W. H. Wickham (A'41); a paper describing the a-c dielectric-loss and power-factor method for field investigation of electrical insulation by F. C. Doble (A'12); a paper on impulse strength as a measure of cable quality by L. I. Komives (A'41); a paper on damping and synchronizing torque of the double-fed asynchronous machine by M. M. Liwschitz (M'39); a paper on excitation circuits for ignitron rectifiers by H. C. Myers and J. H. Cox (A'25); a paper on the protection of solid insulation by lightning arresters by D. D. MacCarthy (A'28) and T. J. Carpenter (A'38); a paper on the measurement of body currents by Doctor Robert S. Schwab; a paper on the theory of torsional dampers as applied to the reduction of conductor vibration by J. M. Speight; a paper describing a new transformer for base-load stations by Philip Sporn (F'30) and H. V. Putman (M'32); a paper on the relative accuracy of three-phase metering combinations by C. T. Weller (M'21); a paper describing a simple method for determining ratio error and phase angle in current transformers by E. C. Wentz (A'28).

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Progress in the Art of
Metering Electric Energy

I—Origins

This first article in a series of four on the historical background of the metering art, sponsored by the AIEE committee on instruments and measurements, deals with origins and development up to 1900; the others, covering respectively (II) progress in the art from 1900 to 1925, (III) special applications, and (IV) calibration and installation of meters, will appear in future issues

AN INDUSTRIAL ART is the adaptation through change or combination of material things both new and old to the accomplishment of some desired end. An essential ingredient is skill.

Progress in an art is the integrated result of three major influences. First and most vital, there are the men who for one reason or another have become so deeply interested in accomplishing a given result that there is created a reservoir of human ingenuity sufficient to insure success. Second, there are the technological discoveries in other fields which give these men new materials, tools, and methods by means of which progress in their own art is accelerated. Third, there are the sociological trends, economical, political, and otherwise, which are largely responsible for charting the course to be followed.

There is probably no better example of the working of these forces than the creation and subsequent progress of the art of metering electric energy.

In the year 1879, through the genius, initiative, and industry of Thomas A. Edison, the incandescent electric lamp became a commercial reality. Three years later, on September 4, 1882, Edison put in operation the Pearl Street generating station in New York City.

Because of vigorous opposition on the part of the then predominating gas interests, and the great difficulty of interesting capital in the new enterprise, the development of this industry which today has become almost indispensable to human welfare, might have been greatly retarded. That it was not so retarded is due, in part at least, to the invention of a new art—the art of metering electric energy. Edison himself realized, probably earlier than anyone else of that time, the necessity for a meter to measure the commodity that he proposed to sell, and was the first to develop and make available a commercial measuring device for this purpose.

An early form of Edison's meter is shown in figure 1*a*. This meter is technically an electrolytic-deposit meter, but it is known to the industry as Edison's "chemical meter". Just as the first automobiles took on the physical form of horse-drawn carriages, so Edison's meter borrowed from the common method of selling commodities and measured electricity by the ounce.

His meter consisted of a jar containing an electrolyte in which two metal electrodes were submerged. A known proportion $\left(\frac{1}{974}\right)$ of the electrical current was made to flow between the two metal electrodes. Over a period of time the weight of metal transferred electrolytically from one electrode to the other was proportional to the amount of electricity (ampere-hours) that had passed through the meter in that period. Therefore, to "read" this meter it was necessary to weigh the electrodes at the beginning and at the end of the billing period. From the decrease in weight of one of the electrodes it was possible to calculate the ampere-hours of electricity used by the customer.

This meter obviously was not a true energy-measuring device, since the amount of metal transferred from one electrode to the other was independent of the voltage of the system. Furthermore, the accuracy of this meter was affected by variations in the temperature of the electrolyte. Consequently a copper coil was placed in series with the jar to compensate for the temperature coefficient of resistance of the electrolyte and thus make the total temperature coefficient of the branch circuit equal to that of the German-silver shunt. In addition to this copper coil there was sometimes another coil operated by a thermostat, primarily to prevent the electrolyte from freezing. Later, because of the change to alternating current on most systems, the fact that this meter would not operate on that type of current was a disadvantage.

Operating troubles were both more varied and more numerous. Removing the electrodes and weighing them presented many difficulties to the meter "reader", called in

This report was initiated and sponsored by the AIEE committee on instruments and measurements as part of its regular activities for 1940–41, under the following direction: I. F. Kinnard, West Lynn, Mass., chairman; A. S. Albright, Detroit, Mich., vice-chairman; T. S. Gray, Cambridge, Mass., secretary. Personnel of subcommittee on watt-hour meters: A. S. Albright, chairman; D. T. Canfield, Lafayette, Ind., editor-in-chief; A. L. Brownlee, Chicago, Ill.; A. B. Craig, Boston, Mass.; J. S. Cruikshank, Baltimore, Md.; C. L. Dawes, Cambridge, Mass.; A. P. Good; Stanley Green, Lafayette, Ind.; F. C. Holtz, Springfield, Ill.; H. C. Koenig, New York, N. Y.; Paul MacGahan, Newark, N. J.; C. V. Morey, New York, N. Y.; H. C. Rankin, Boston, Mass.; A. R. Rutter, Newark, N. J.; F. B. Silsbee, Washington, D. C.; G. R. Sturtevant, Lynn, Mass.; and H. L. Thomson, Hartford, Conn.

Following publication of part IV in ELECTRICAL ENGINEERING, the whole report will be issued in pamphlet form.

Figure 1b (left). Thomas A. Edison

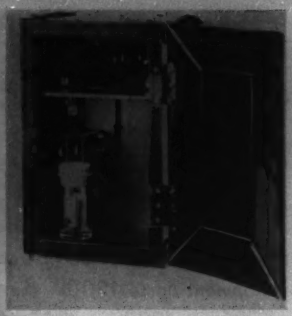


Figure 1a. Edison chemical two-wire meter

those days a "calculator". The meter was not, in other words, self-indicating. The customer could not read his own meter. It is interesting to note in an early report of the meter committee of the Association of Edison Illuminating Companies that considerable space was devoted to ways and means of fostering customer good will. One suggestion was that the electrode plates be weighed in the presence of the customer.

By the close of the first decade in metering progress, ending in 1890, the human ingenuity applied to the metering art had been greatly augmented. The next man to make a great and lasting contribution to the measurement of electric energy was Professor Elihu Thomson, co-founder of the Thomson-Houston Electric Company at Lynn, Mass., which later became the nucleus of the General Electric Company. Of many meters invented by Thomson, the one that had the greatest influence upon the metering art, is shown in figure 2*b*. This meter, first manufactured in 1889, was a true energy-measuring device, probably the first to be used commercially in America. It was first known as the "TRW" meter, meaning Thomson recording wattmeter; then as the "mechanical meter" to differentiate it from Edison's chemical meter, and the "universal meter" since it was used extensively on both a-c and d-c systems; and finally as the "Thomson watt-hour meter". This meter was, in effect, a small shunt motor, with the field or current coils of heavy wire connected in series with the line, and the armature of fine wire connected across the line. The currents in the two windings were proportional to the line current and voltage respectively, and the torque of the motor, therefore, was proportional to the power. The braking or retarding mechanism consisted of a copper disk mounted on the armature shaft which was caused to rotate between the poles of three permanent magnets clamped to the bottom of the base. Since the magnetic braking torque varied directly with the speed, the number of revolutions of the meter in a given period became a measure of the amount of energy passing through the meter during that period. The meter had a set of dials upon which the result of this action was recorded.

Although Professor W. E. Ayrton in England appears to be the first to have conceived the idea of controlling the speed of a motor meter by utilizing the action of a permanent magnet flux upon a damping disk, Thomson first applied the principle to make a commercially successful meter.

Thomson's meter overcame most of the technical and all of the operating difficulties of Edison's chemical meter. Although its accuracy was not up to our modern standards, it was remarkable for a meter of any kind in the late 1880s. It rapidly became the recognized standard instrument for the measurement of d-c energy. The most significant fact about this meter is that the basic principle of its operation, perfected by Thomson more than 50 years ago, is used today without change in all d-c commutator-type motor meters of whatever manufacture.

Between 1890 and 1900 Thomson and W. H. Pratt made many basic improvements in this meter. The original cast-iron bases were replaced by bases made of a nonferrous metal. This change improved the meter's performance, particularly on direct current. Fixed coils in series with the armature and arranged to augment the field in which the armature operated appeared early in the development. These coils, called at that time "starting coils," were the first devices aimed at compensating the meter for friction. The adjustable form of this coil appeared first about 1900. Also at this time, direct-reading registers (those not requiring multipliers) became more or less standard and shortly thereafter the first anticreeping device was added. The term "creep" as applied to watt-hour meters refers to the tendency of the meter disk to rotate under "no load" conditions. Creeping is a result of the addition of compensating means of various kinds to meters to improve their starting performance and to improve accuracy at light load. The first anticreeping device consisted of a piece of steel wire clipped over the edge of the disk. The tendency to creep was stopped when the clip was brought within the field of the permanent magnets by rotation of the disk. This device was first used by F. G. Vaughen in 1901.

The technological developments that influenced the invention of a meter strictly for alternating current were the enunciation of the principle of the revolving magnetic field by Galileo Ferraris of Turin, Italy, in 1885; the invention of the transformer by Lucien Gaulard and John D. Gibbs

about 1882 and its perfection and adaptation in America by William Stanley in 1886; and the invention of the induction motor by Nikola Tesla in 1887. Briefly, the principle enunciated by Ferraris was that to produce a torque or force on an armature free to rotate, it must be acted upon by two alternating current fluxes which are: (1) not in time phase with each other, and (2) applied to the armature in two different places along the direction of proposed motion. The inventions of the transformer and the induction motor are significant because they made possible the a-c system and thereby greatly stimulated the effort to provide meters for alternating current only.

The result of these influences upon the art under discussion was the development of a meter operating exclusively on alternating current, invented by Oliver B. Shallenberger, who at that time was a design engineer with George Westinghouse, founder of the Westinghouse Electric and Manufacturing Company, at Pittsburgh, Pa.

Shallenberger's a-c meter is shown in figure 3*a*. It was not a watt-hour meter, but an ampere-hour meter. The patent issued to Shallenberger covering this meter was granted in 1888. It included at least the basic principles of an a-c watt-hour meter. Shallenberger was apparently of the opinion that the simpler ampere-hour meter would be in more demand at that stage of the art than the more complicated watt-hour meter and therefore the former was put in production first. This ampere-hour meter had but one pair of coils through which the line current passed. A second pair of coils at an angle with but in close proximity to the current coils received energy by induction from these coils. The disk or revolving element of the meter was placed inside both pairs of coils. Air-vane braking was used. At the relatively low speeds at which the meter operated, the braking torque was proportional to the square of the speed. Thus the number of revolutions made by the meter in a given period was made proportional to the ampere-hours passing through the meter during that period.

The simplicity and low cost of Shallenberger's meter caused the operators to adopt it with alacrity for a-c circuits. However, as the use of alternating current increased, the fact that Shallenberger's meter measured ampere-hours and not watt-hours created a preference for Thomson's meter.

The sociological trends as gleaned from the reports of meter committees of the period indicate that the requirements of the central-station industry had far outstripped the availability of meters and large amounts of electric energy were being sold on a "per lamp" basis. By the end of the decade 1880–90 all such committees were definitely recommending that this practice be stopped, and that in all large cities, at least, meters be used. This decision to substitute a metered rate for the flat rate then prevalent was brought about largely by the availability of Thomson's and Shallenberger's meters.

The final stage in the origin of the art of metering was reached in the decade between 1890 and 1900. Although other interests had claimed Edison's attention and he was no longer actively interested in meters, the factor of human skill was increased by the work of Thomas Duncan and Robert C. Lanphier. The former founded the Duncan Electric Company at Lafayette, Ind., in 1901, and the latter was a major influence in the founding of the Sangamo Electric Company at Springfield, Ill., in 1899.

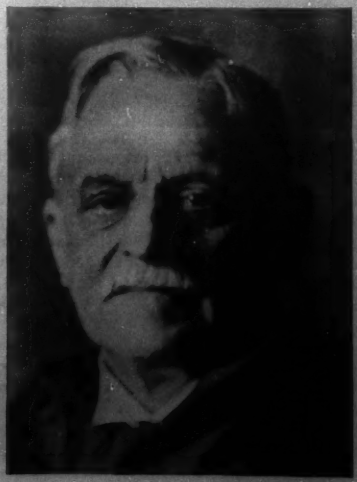
At the time under discussion (1890) Duncan was designing meters for the Fort Wayne Electric Light Company at Fort Wayne, Ind. An early meter manufactured by this company is shown in figure 4*a*. It was known as the Duncan Fort Wayne meter. It was an ampere-hour meter and was identical in principle of operation with Shallenberger's meter, differing only in the physical form and arrangement of its component parts. It carries a patent date of 1894.

Lanphier entered the metering art in the fall of 1897, soon after his graduation from Yale, through a chance meeting with Jacob Bunn, Jr., vice-president of the Illinois Watch Company. Bunn persuaded Lanphier to undertake certain experiments on a meter designed by a German inventor, L. Gutmann. On September 13, 1897, Lanphier reported for work and was given space in an unused outbuilding of the Illinois Watch Company. This was the beginning of the Sangamo Electric Company, the subsequent contributions of which rank it among the leading meter manufacturers of today. An early Gutmann meter is shown in figure 5*b*. These meters were the first manufactured by the Sangamo Electric Company.

About the middle of this decade occurred the greatest

Figure 2a (right). Professor Elihu Thomson

Figure 2b. First commercial "Thomson recording wattmeter" manufactured by the Thomson-Houston Electric Company, September 18, 1899



single technological discovery or invention ever made in the art of metering electric energy. If one may liken an electric meter to the human body, this discovery was its heart. The man who made this vital contribution was Oliver B. Shallenberger, who discovered how the induction meter, which recorded ampere-hours, could be made to record watt-hours or energy. To the initiated in the profession of metering, the method he discovered is known as the lagging process.

To understand the exact nature of this process it must be realized that an instrument which is ultimately to record energy must first produce on the moving element a torque or force which is at all times proportional to the power flowing in the circuit to be measured. The first step in the accomplishment of this result is that there be at least two coils. One coil is connected across the circuit in such a manner that the flux created by it is proportional to the voltage and the other is connected in series with the circuit so that the flux created thereby is proportional to the current flowing in the load. Shallenberger pointed out that if the combination of these two fluxes upon a rotatable member is ever to produce a force on that member proportional to power the flux produced by the potential coil must be caused to lag in time behind the voltage of the circuit by exactly one quarter of a cycle. He produced this desired time relation by means of a lag coil placed on the potential-coil pole.

For those not familiar with the art, it is sufficient to realize that this lagging process is absolutely essential whenever a-c energy is to be measured correctly by an induction-type meter.

Figure 6 shows the four watt-hour meters which, with but slight use of poetic license as to time and place, can be said to be the start of nearly 50 years of progress in the art of metering electric energy. Meter (*a*) is an early model of Shallenberger's first watt-hour meter. It was offered for sale in 1894 for approximately $15. It was a true energy-measuring meter of the induction type, and the first to be placed in commercial use in this country.

Meter (*b*) is the result of basic design work by Thomson and Pratt, and appeared on the market in the fall of 1897. It was the first induction-type watt-hour meter produced by the General Electric Company and superseded the commutator-type Thomson watt-hour meter of 1889 for a-c service.

Meter (*c*) is an experimental model of a watt-hour meter designed by Thomas Duncan about 1892. It is probably the first use of a single disk in a meter of this type. It is not a commercial meter, and never appeared on the market.

Meter (*d*) was designed by Gutmann and manufactured by the Sangamo Electric Company. The first shipment of these meters was made in 1899. The Gutmann meter had a rather short life, owing to patent difficulties, but it was the first watt-hour meter to be manufactured by the Sangamo Electric Company.

The Gutmann meter is of particular interest to the student of the art because of the ingenious method employed in an attempt to avoid infringement of the Tesla patents. Gutmann mounted his potential and current electromagnets so that there was no space displacement between them in the direction of proposed motion of his moving element. This space displacement is an essential element as Ferraris' original statement shows. Gutmann obtained the essential space displacement by cutting spiral slots in his armature, thereby causing the induced current to move sidewise.

By the end of the decade, at least two other meters were on the market, one by G. A. Scheeffer and another by Stanley. The Diamond meter of this period, and the Columbia, Holcomb and Hoke, and Sewickley meters of a later period were all of Scheeffer design. Scheeffer was active in the art from about 1895 to 1920.

Stanley's work in meters is of particular interest because he was the inventor of the magnetic flotation meter. This meter had no bearings as such. The disk was suspended or floated in the magnetic flux. It was held in place by a wire thread through a hollow shaft and a hub. Such a principle required very large fluxes and the first meters could be built only for large current ratings.

The record would hardly be complete if mention were not made of one other type of meter—the Faraday disk or mercury-motor type of quantity meter. This principle

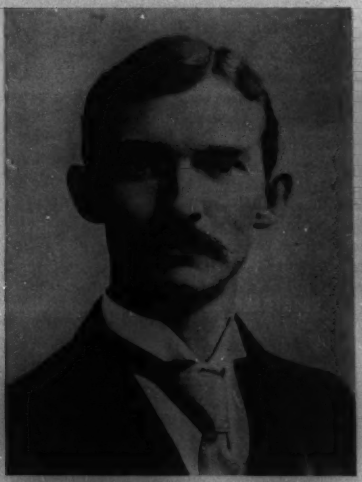


Figure 3b (left). Oliver B. Shallenberger

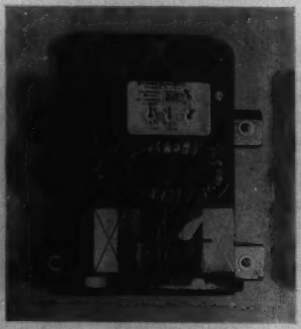


Figure 3a. Shallenberger ampere-hour meter

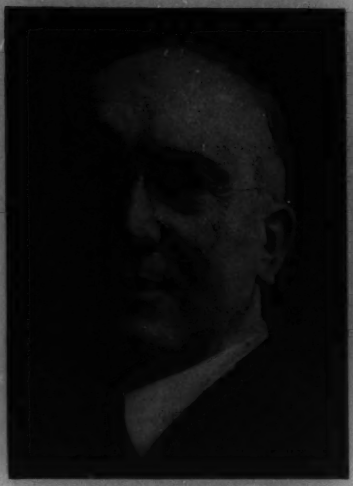


Figure 4a. Duncan Fort Wayne ampere-hour meter

Figure 4b (left). Thomas Duncan

turn of the century. It is instructive in this respect to read the minutes of some of the early meter committees of the Association of Edison Illuminating Companies. In this way may best be understood the trend that early progress was to take. Among the members of this committee were J. W. Lieb, New York Edison Company, L. A. Ferguson, Chicago Edison Company, and Alex Dow, Detroit Edison Company.

In 1899 these men were asking for "a meter having light load adjustable for local conditions; hence a meter which will not creep, and will yet be accurate on light loads; a meter which will be unaffected by short circuits; a meter which will be substantially dust proof, and which will have outside binding posts." And again "A meter that can be shut up and let alone and which it would not be necessary to clean and adjust every six months would be an improvement, and we think that the matter still requires study and action."

Finally one notes that these more or less general requests made in the spirit of hopefulness, and no doubt without much expectancy of immediate fulfillment, were instantly accepted by the various manufacturers. Their engineers reported back to the committee that the following improvements would be undertaken.

"First, a dust and insect-proof cover.

"Second, a cover and frame so shaped and retained together as to

seems to have been embodied first in a meter by George Hookham and S. F. de Ferranti in England about 1888. Rotation of a copper disk partly or wholly submerged in mercury was produced by the interaction of a suitable permanent magnet with an electric current through the disk. In the United States the fundamental discoveries of E. S. Halsey of the General Electric Company were instrumental in increasing the efficiency of the mercury meter and making it a practical device. However, Lanphier of the Sangamo Electric Company is entitled to much of the credit for the early practical application of this meter.

Figure 7 shows the three meters just discussed. Meter (*a*) is an early meter by Scheeffer which was built by the Diamond Meter Company at Peoria, Ill. Meter (*b*) is one of Stanley's magnetic flotation meters manufactured at Great Barrington, Mass. Meter (*c*) is an early mercury meter by Lanphier, a product of the Sangamo Electric Company.

Admittedly, the four meters with which progress in the art of metering electric energy started were crude, inefficient devices needing constant attention to keep them operating with even reasonable accuracy, but similar difficulties are encountered in the early stages of any art.

Probably no one realized the need of improvement to a greater extent than did the operators themselves at the

Figure 5a (right). Robert C. Lanphier

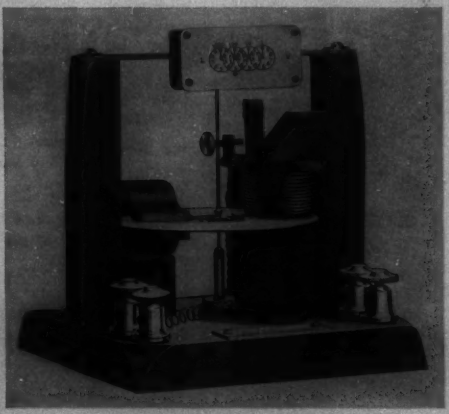
Figure 5b. An early Gutmann a-c watt-hour meter

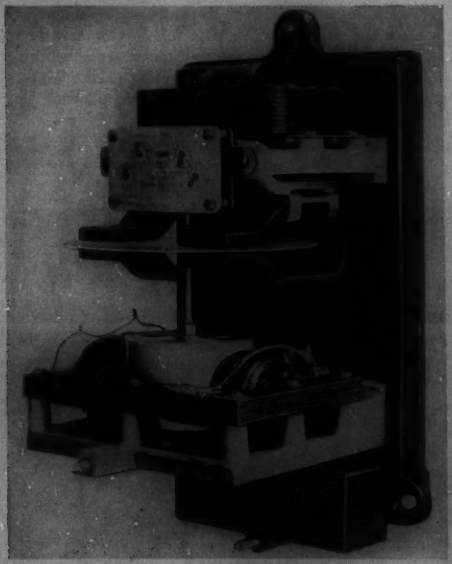
render dishonest and curious tampering with the internal mechanism as nearly impossible as may be.

"Third, means for fully protecting from malicious tampering the heads of all screws in the base which bind the damping magnets, etc., in place without rendering them inaccessible to those authorized to reach them.

"Fourth, means for protecting the damping magnets from the occasional depolarizing effect of severe short circuits.

"Fifth, means for immediate and close adjustment of light-load accuracy to meet local conditions without affecting the general calibration."





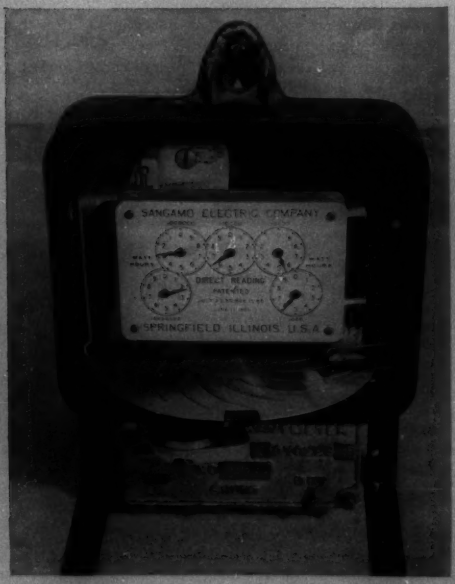


Figure 6a (top left). Shallenberger watt-hour meter
Figure 6b (above). Thomson a-c watt-hour meter
Figure 6c (top right). Duncan watt-hour meter, experimental model
Figure 6d (right). Gutmann a-c watt-hour meter

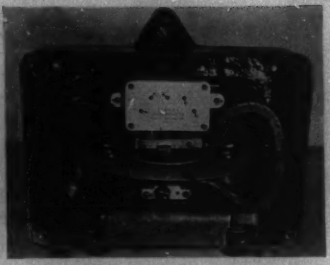


Figure 7a (above). Scheeffer a-c watt-hour meter

Figure 7b (top right). Stanley's magnetic flotation meter

Figure 7c (right). Early mercury motor meter by Lanphier

In these historical statements may be found, to the credit of the manufacturers, a spirit of co-operation which has been fostered over the intervening years until today it ranks as one of the best in industry.

In the minutes of a meter-committee meeting of today, such phrases as "accessibility," "tamper proof," "greater accuracy," "longer inspection periods," are still in frequent use, but it would be wrong to assume that no progress has been made. The correct deduction is, rather, that American meter practice never has been and never will be satisfied. This concept is essential to understand and to appreciate the vast progress that has been made in the art of metering electric energy since 1900.

How and when further improvements were carried out will be covered in the subsequent sections of this report.

It is fitting to conclude this section with a final word about the pioneers. Shallenberger, who died in 1898, did not live to see the true significance of his great discovery. Thomson lived until 1937 and saw the results of his outstanding accomplishments. The remaining pioneers died in the following order: Duncan in 1929, Edison in 1931, and Lanphier in 1939. Because of Schallenberger's ill health, most of his work had been taken over prior to his death by Doctor Frank Conrad of the Westinghouse Electric and Manufacturing Company. All the pioneers, therefore, lived to see the art they helped to create in capable hands, and most of them were active throughout the period of its growth. Of the other men whose names have been mentioned, only Pratt, Vaughen, and Conrad are alive today.

Westinghouse Builds Fluorescent-Lamp Plant

INDICATIVE of the rapid growth of the fluorescent-lamp industry is the $3,000,000 "black-out" plant completed in August at Fairmont, W. Va., by the Westinghouse Electric and Manufacturing Company. Built in less than five months, the first units of this plant comprise a single-story main factory building 224 feet wide and 885 feet long, auxiliary buildings, bus terminal, parking lot, and water reservoir, all fenced and floodlighted for protection. Initial production is scheduled to be 50,000 fluorescent lamps daily; ultimate 200,000.

The windowless factory building is zone air-conditioned throughout and fluorescent-lighted to an intensity of some 40 foot-candles. Some 5,100 40-watt lamps, of a "soft white" color to preserve natural color values, are mounted in open-end luminaires hung end-to-end to form continuous troughs about 12 feet apart and at heights ranging from 10 to 13 feet as required. As dust-free air is especially important in the manufacture of fluorescent lamps, the "black-out" construction was a matter primarily of manufacturing rather than war-time expediency, although provisions have been made to prevent light leakage at doorways and the roof has been treated to prevent tell-tale reflections on moonlight nights. An electrostatic precipitator supplements the regular air-conditioning equipment to remove 90 percent of all air-borne dust or smoke particles, and some 600 "Sterilamps" irradiate the cleaned air in the ducts to destroy bacteria and other micro-organisms. Because some 40,000,000 cubic feet of natural gas per month will be burned in glass working, air will not be recirculated in manufacturing areas. Gas-fired unit heaters will provide winter heating as required. Cooling water (initial capacity 3,600 gallons per minute at 55 degrees Fahrenheit) is drawn from a near-by abandoned coal mine.

To provide required reliability of service and to facilitate subsequent plant expansion, a three-phase, four-wire, 208/120-volt secondary network system of electric power distribution was used. Reliability of the network is enhanced by feeding it from two different 66-kv transmission lines through duplicate 3,000-kva self-protecting transformers of the unit-substation type, and duplicate 6.6-kv feeders to duplicate sets of three 500-kva 3-phase air-cooled network transformers.

Scheduled for completion by May 1942 on the same 95-acre property is a $1,800,000 glass factory intended to supply the glass tubing required by the lamp factory. The manufacture of small incandescent lamps, such as automobile and Christmas-tree lamps, is scheduled to be transferred to Fairmont upon completion of the glass plant.

Fires of Electrical Origin in Factories

G. S. LAWLER
MEMBER AIEE

Maintenance of electrical equipment in a manner appropriate to its importance is urged as a means of combating an increasing proportion of industrial fires of electrical origin

NO ONE will question the statement that electricity in its various uses is a potential source of fire hazard. It usually is kept well under control, but too frequently it "kicks over the traces" and so-called breakdowns occur, many times attended by excessive local heating which ignites insulation, and fire spreads to near-by combustible materials. After a fire starts, conditions determine its extent. Usually it is quickly put out, but sometimes it causes serious loss. It has been said that the lack of a horseshoe nail caused Napoleon to lose the Battle of Waterloo. A case is known where the breaking of some small washers needed to limit the travel of the movable contacts of an oil switch finally resulted in a fire which so damaged an exceptionally large manufacturing plant that 80 per cent of its power requirement was interrupted for about 1½ days.

Electricity is by far the principal cause of fire in the properties insured by the Associated Factory Mutual Fire Insurance Companies. For the year 1940, of all fires reported to them for which claim was made, 21.9 per cent were of electrical origin, and this figure does not include the losses to electrical equipment when lightning was the initial cause. About 5 per cent can be added if lightning losses are included. The amount of all electrical losses in 1940 was 13.9 per cent of the total loss occasioned by fires of all causes. No exceptionally large single electrical loss occurred last year, so the percentage happens to be fairly low. In 1939 it was 65 per cent of the total.

The 1940 fire statistics for the whole United States are not yet available, but for 1939 it was estimated that about 9 per cent of the total number of fires reported were of electrical origin. The electrical cause rated third in importance, smoking being the first and sparks on roofs the second.

The Factory Mutual experience as regards the proportion of electrical losses is higher than that of the United States as a whole, because the Mutuals insure manufacturing plants almost entirely. The average plant value is high and most of them contain extensive electrical equipment. The proportional value of electrical equipment in such plants is much greater than the corresponding figure for the average property throughout the country.

To give some idea of what these proportions are in industrial plants, the percentages applying to a few typical plants for which figures are available are given. A certain large modern newsprint paper mill has 20.6 per cent of its total insurable value in its electrical equipment. If it had its own generating plant the figure would be higher. An up-to-date cotton mill has 4.1 per cent of its value in electrical equipment; a hosiery mill 3.7 per cent; a lace-curtain mill 4.1 per cent; an average machine shop 2.8 per cent; a rubber-product plant 7.6 per cent; a laundry 6.4 per cent; and a large plant making electrical apparatus 12.0 per cent.

In industrial plants and utility properties may be found nearly every type of electrical apparatus made, from the smallest to the largest. The voltages range from the lowest to the highest. The equipment is operated and maintained under varying conditions, some by experts and some by those having less knowledge of the equipment they are handling than it deserves. As practically all electrical equipment is inherently a fire hazard it is not at all surprising that many breakdowns occur.

Some fires of electrical origin, therefore, are to be expected under the best conditions. What a reasonable proportion is remains a matter of conjecture, but it should be less than the 21.9 per cent mentioned, provided the electrical equipment is of suitable type, well designed and constructed, properly installed, and given the attention its importance warrants.

As a simple gauge for estimating whether electrical fires are being kept under control from year to year, it has been assumed that the rate at which electrical equipment has been installed and kept under normal load conditions varies roughly with the yearly output of the utility generating plants in the country. Such a study has led to the belief that before the depression we were holding our own, but since then we have been losing somewhat.

Essential substance of a paper presented at a meeting of the AIEE Lynn (Mass.) section March 11, 1941.

G. S. LAWLER is chief electrical engineer, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

Under the present and future forced manufacturing conditions caused by the war, we are likely to have a greater proportion of electrical fires than we should unless something is done to check them.

It should not be overlooked, however, that although the number of electrical fires is large and increasing, the use of electricity has resulted in a decrease in the number of fires due to other causes, such as flame-type lamps, shafting, and belting. The increase in number is also offset by the benefits which electricity confers, for many of the present processes used in manufacturing plants would be impossible without this form of energy.

It may be of interest to see where most of these electrical fires begin. The principal offenders are motors. The figures for 1940 indicate that 29.3 per cent of the fires originated in motors of one kind or another. Overheating, resulting from overloads, multiphase motors running single-phase, or stalling, caused a small proportion of the breakdowns, but by far the most were due to failures of winding insulation which resulted in arcing of sufficient intensity to ignite the insulation. In a large proportion of these accidents the fires were confined to the motors, but in many instances the fires spread to combustibles near by. Where the fires have spread, the damage to the motors usually has been only a small part of the total loss, but this is equally true of other spreading fires regardless of the type of apparatus in which the trouble originated. In only a small proportion of the accidents were defects in materials or faulty design the cause of the trouble. Age, bad operating conditions, or lack of proper care of equipment mostly were to blame.

By far the largest number of motors giving trouble were of the squirrel-cage type, but this could be expected because this type of motor predominates in industrial plants by a large margin.

Defective wiring was responsible for 25.5 per cent of the electrical fires. This class is a very broad one and includes transmission, distribution, and branch-circuit conductors, their enclosures, connections, and supports—that is, about everything except the utilization apparatus and its control, protective, and other devices. There are innumerable splices and connections, any of which may become loose. The fact that wiring is in conduit or other type of raceway does not make it immune from possibility of breakdown. A common danger point is where conductors bear on bushings at the ends of conduit lines in cabinets or junction boxes. Vibration or the weight of the conductors in time may damage the insulation so that grounds or short circuits take place. Failure of insulation is frequently accelerated by overloads which some conductors carry. Excessive temperatures cause the insulation to become dry and brittle, and therefore likely to crack or break, especially if disturbed.

The average amount of loss per fire due to breakdowns originating in wiring is greater than for most classes of electrical fires, as more of the fires spread from their point of origin and involve building contents. Also sprinklers are more likely to operate, with consequent damage by water.

Switches and controllers of various kinds were responsible for 17.7 per cent of the fires. There are a great many types of these devices, all of which have moving parts and screw or clamp connections. Moving parts are always subject to wear. Wear is likely to result in loose parts and poor contacts. Screw or clamp connections are likely to become loose, due to vibration, unless checked and tightened occasionally. Manufacturers of controllers have produced very compact devices which are placed in boxes of small dimensions. A short circuit occurring in these small boxes is likely to develop quickly into a more serious one. In addition, the expansion of the air and the gases frequently blow the covers open, allowing molten material to drop or be thrown onto near-by combustibles before the protective devices farther back on the lines can operate.

Differential relays failed to prevent destruction of rotor and stator windings of this 25,000-kva generator. A short-circuit ignited exposed insulation

Oil-immersed autotransformer-type starters have occasioned more fires than other types of starters. This is because the coils have a short-time rating, and because of the presence of oil. Frequently the coils are left in the circuit too long. In a short time they burn out, a short circuit follows, and ignited oil is violently expelled.

The remaining 27.5 per cent of the fires of electrical origin started in many different types of apparatus, such as generators, transformers, circuit breakers, fuses, lamps, resistors, and reactors; also miscellaneous pieces of special equipment used for various purposes. Their troubles are due to a variety of causes, each kind of equipment having its own special weaknesses.

While the proportion of generator fires is small, this is because of the small number in use compared with other kinds of apparatus. The individual loss, however, is

likely to be large, as generators are usually of large size and considerable value. A fire in a turbogenerator is almost always serious as far as the generator itself is concerned, unless special means of extinguishing it are provided.

Fire underwriters always emphasize the need of protecting against the hazard occasioned by oil-type transformers. While these transformers are as free from troubles as any type of equipment, they do fail occasionally. Owing to the large amount of oil in them, a fire, if it occurs, is likely to be a large one; and unless the transformers are so located and protected that the fire will be limited to them, great damage to other property may result. Generally, transformers are guarded unusually well as far as other property is concerned, but even so the damage by fire alone in 12 such fires in 1940 averaged over $1,600 per fire. This does not include the damage done by the electric current. If some care had not been taken to separate the transformers from other property the loss would have been much greater. Fortunately, in most cases, there is little or no difficulty in placing them where fire will be limited. Transformers containing nonflammable liquid now available can be located almost anywhere, as far as their fire hazard is concerned. The number of these in use is increasing, partly because expensive precautions are unnecessary, and partly because in spite of their greater cost the over-all cost of an installation may be less than for transformers of the oil-immersed type.

There are four factors that chiefly influence the fire hazard of electrical installations:

1. Their design and construction.
2. How they are installed.
3. How they are operated.
4. The quality of maintenance they receive.

If all these factors were given careful attention there would be a much smaller number of electrical fires and such fires as did occur would be considered reasonable. In some plants all four of these factors have received generous attention and consequently the fire record has been excellent. In many other plants, however, one or more or even all of the factors have been more or less neglected and their electrical-fire records have suffered accordingly.

The first and second factors, namely, construction and installation, are the ones to which inspection bureaus and departments have given most attention.

The first is handled by requiring that, as far as obtainable, apparatus, devices, and materials used be approved by a recognized testing laboratory and included in the laboratory's published list of approved devices. All types of equipment cannot be put through the laboratories, but those in general use are. Motors, generators, power and most lighting transformers, and similar heavy apparatus are not passed upon.

The laboratories examine and test apparatus submitted to them, and if the design and construction is deemed satisfactory according to their standards, and the equipment meets certain test requirements, it is approved and listed. Such a list can be obtained by anyone desiring a copy.

Installation is taken care of by requiring compliance with the rules of the National Electrical Code.

If an installation comprises apparatus, devices, fittings, and materials well selected for the purpose, approved by the authorized laboratories, and installed in accordance with the National Electrical Code it starts its career in the best possible shape. If it more or less departs from what is considered an excellent installation in these regards, then the chances of later trouble followed by fire increase, the increase depending upon the degree of departure. Some departures are intentional and result from a desire to cut first costs, while others are due to lack of proper knowledge.

After an installation is in, the third and fourth factors, namely, operation and maintenance, become very important. If the equipment is operated as it should be and is not abused by overloading or mishandling, and if it receives the degree of maintenance it should, considering the conditions to which it is subjected, little or no trouble will be experienced. If, however, even the best equipment is abused and neglected, breakdown with its attendant probability of fire is almost sure to occur.

The inspection bureaus and departments in general give very little attention to electrical equipments after they have been approved at time of installation, unless some accident directly calls their attention to undesirable conditions.

Experience clearly indicates that the degree of maintenance which electrical equipment receives is fully as important as, if not more important than, the care with which it is installed, as an influence on the accident and fire record. A poor installation given good care by an able conscientious electrician usually will give less trouble than an installation that originally was excellent but cared for by an incapable, careless electrician. The fact that an equipment is old and antiquated does not always mean that it is poor from a fire standpoint. It still may be as good as when installed. A manufacturer cannot be expected to change his equipment to comply with each successive edition of the National Electrical Code as it is produced, but he can keep it in good condition.

Accurate figures of the proportional number of fires which can be attributed to lack of proper care and maintenance are difficult to obtain, but the proportion may be as high as 50 per cent. Factory Mutual figures for 1940 indicate 42 per cent, but this is probably low. The proportion has been increasing ever since the recent depression started. Business became so poor that many plant managements cut maintenance to the bone, and even into it. Many undoubtedly thought that when business conditions improved they would get their equipment into shape again before it had received permanent injury. Some evidently thought, if they gave it *any* thought, that electrical equipment would stand up almost indefinitely without care. The result has been that many

equipments have been neglected for so long that permanent injury has resulted. When they have been called upon to resume their normal, or near normal, loads, breakdowns followed by fires have occurred.

The present great increase in activity in production due to the war has, and will have, an accumulating effect on the number of breakdowns and fires. The degree of maintenance equipment receives will be a very important factor in this regard.

At plants operating additional shifts or almost continuously, the length of time important equipment can be shut down for repairs and attention is too short to accomplish desired results unless additional men are assigned to the work. It is difficult to get experienced men at present. The result is sure to be more breakdowns and fires with their attendant effect upon urgent production. An increase in the number of fires has already been noticed.

Any experienced man in charge of electrical equipment knows what constitutes reasonably proper maintenance. The equipment should be visited and checked at intervals suitable for the conditions under which it operates. Moving parts should be checked for wear, and adjustment and minor repairs made at the time any weakness is found. Major repairs should be made just as soon as possible. Switches, controllers, and circuit-breaker contacts should be smoothed if rough, and replaced if necessary. Oil should be kept at the proper level in oil-immersed apparatus and in the bearings of rotating machinery. Oil in transformers should be tested at suitable intervals and filtered or replaced as needed. Doors of cabinets containing electrical apparatus should be kept closed. Dirt and lint should not be allowed to accumulate in cabinets and boxes. Special care should be given to motors. Air gaps should be kept uniform. They should be blown out at intervals depending on the nature and extent to which combustible fly or dirt accumulates on them. Special care should be taken that oil does not get onto the insulation. Overload protective devices should be of proper rating or setting and kept in operative condition. These items are only a few of those that need attention. What should be done, how it should be done, and how frequently, will vary from plant to plant.

In my experience deficient maintenance becomes more quickly evident with motors than with any other class of apparatus. To get a quick general idea of the quality of maintenance in any plant it is only necessary to observe first whether there is any quantity of dirt, and especially of oily dirt, on the motor windings. If there is an accumulation, it is almost a certainty that the rest of the equipment is not being maintained as it should be. Deposits of dry dust or dirt, however, are unavoidable in some plants, such as cement plants, and usually will do little harm unless ventilating ducts are obstructed. If oil is mixed with the dust or dirt a rapid deterioration of the insulation is bound to occur. The presence of oil usually is due to too much being put in the motor bearings. The excess oil escapes around the shafts from the bearings and some finds its way onto the windings. The use of too much oil is frequently occasioned by an endeavor to cut down the number of visits to motors and thus save time and expense. It is believed that a few extra squirts from the oil can will accomplish the desired purpose. Oily dirt on the windings is a principal, if not *the* principal, cause for the position of motors at the head of the list of types of equipment prominent as a place of origin for fires.

Factory Mutual inspectors, during their frequent periodical visits to plants, are instructed to pay particular attention to the way electrical equipment is maintained and to recommend improvements where maintenance is not up to a reasonable standard. This will be emphasized even more in the future than in the past, for it is the most promising way of reducing the electrical loss.

So far only the direct loss due to fire has been mentioned, since fire-insurance companies cover only that type of loss, but many other kinds of loss attend most fires. Some of the other losses are tangible and some intangible. First there is the part of the direct damage caused by the electric current itself. This may or may not happen to be covered by insurance. As it is not covered by the fire-insurance companies, none of the figures given include it. The aggregate of such losses, however, is considerable and in some instances it may be the principal loss. Fires affect production to a greater or less extent, depending on the extent of the fire, the size and type of equipment involved, and the purpose for which the equipment is used. If the effect on production is serious, employees may suffer a loss of wages. Sometimes orders are cancelled if the product cannot be delivered on time. The management and assistants occasionally have to put in extra work in getting things going again and this may be accompanied by considerable anxiety, for other necessary duties have to be postponed until conditions are brought back to normal.

There is no profit to a manufacturer in having a fire. Profits are made by avoiding them. One of the best ways of preventing direct loss and of assuring uninterrupted production, and thereby profits, is to take reasonable measures to have the electrical equipment well adapted to its purpose, well installed, properly operated, and especially to have it receive the care its importance deserves.

A "live" wire, dropping out of a lug on the wall, burned a hole in the grounded tank of a transformer and caused an oil fire in this vault

Radiography at High Speed

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Development of a cold-cathode X-ray tube makes it possible to make records on film of distortion inside objects opaque to visible light, thus supplementing high-speed photography

THE interesting results attained by ultrahigh speed or flash photography are well known to newspaper and magazine readers everywhere. Distortion due to momentary strain can be shown in many familiar objects, such as golf balls and rapidly vibrating open relays. A new technique using X radiation instead of visible light makes it possible to record distortion or change in the interior of opaque objects as well as that visible on the outside.

To make such radiographs at speeds of about one microsecond, enormous currents must be passed through the X-ray tube for that very short time interval. In the conventional hot-cathode X-ray tube, the available electron current is definitely limited by safe cathode temperature and space-charge effects. These limitations are avoided by the use of a cold-cathode X-ray tube recently developed in the Westinghouse lamp research laboratories at Bloomfield, N. J.

In place of the conventional filamentary cathode, this tube employs a pair of cold electrodes *G* and *H* (figure 1). *G* is the true cathode and is so shaped and located with respect to its auxiliary electrode *H* that enormous potential gradients are built up when voltage is applied between these electrodes. Under the influence of these high gradients, a copious supply of electrons is obtained by cold emission from electrode *G*. Currents of from 1,000 to 2,000 amperes pass through the tube for periods of about one microsecond. The X-ray energy produced under these conditions is sufficient to produce radiographs of many objects in this short time interval, and consequently rapidly moving objects may be radiographed without blur caused by motion.

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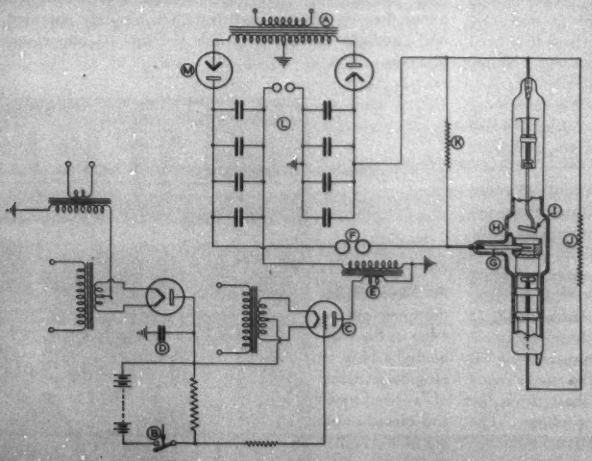
Figure 1. Circuit diagram of the new ultrahigh-speed X-ray tube and auxiliary equipment



Operation

A—High-voltage transformer for charging capacitors *L* through rectifiers *M*. When timing circuit is broken at *B*, a negative charge on the grid of thyratron *C* is dissipated, allowing capacitor *D* to discharge through the primary induction coil *E*. This voltage is carried through main capacitors, causing spark gap *F* to break down, activating the X-ray tube. This places the total voltage between the negative or cathode electrodes *G* and *H*. Cold or field emission working across this narrow space causes electrons to be pulled from the cold metal of *G* to *H*. As soon as this current starts to flow, the voltage between *G* and *H* diminishes, and the electron stream from the cathode "hot spot" on *G* is diverted to the anode *I*, directed or focused by *H*. X rays are generated at *I* by the impact of this electron stream. The diminution of voltage is caused by blocking action of high resistance *J*. Resistance *K* is placed directly across the capacitors and gap to insure that the breakdown at gap *F* will be consistent with its spacing

Constants

A	125 peak kv, 5 milliamperes, center grounded
Valves	125 peak kv inverse—10 milliamperes
Capacitors (*L*)	60 kv direct current 0.04 microfarad (two only needed for most applications)
D	4 microfarads, 1,000 volts,
E	Equivalent of an automobile coil giving a negative high-voltage impulse approximately 20 kv
K and *J*	Approximately 100,000 ohms

a) Bullet entering block

(b) Bullet has entered block; note rapid closing of hole by wood fibers

(c) Bullet emerging from block

(d) Bullet has left block. Note lead particles broken from bullet in its passage

Figure 2. Radiographs showing penetration of a projectile into a wooden block

A basic circuit is shown in figure 1. The high-voltage transformer *A* feeds capacitors *L* through rectifiers *M*. Capacitors are charged to a potential slightly less than that required to break down the gap *F*. When it is desired to fire the tube by passing the capacitive charge through it, the firing circuit is opened at *B*. This permits the negative charge on the grid of the thyratron *C* to leak off and the charge on capacitor *D* then passes through the thyratron and through the primary of induction coil *E* to ground.

This sudden passage of current produces a high voltage in the secondary of *E*, which raises the potential of capacitor bank *L* so that the total voltage across the capacitor is now great enough to break down gap *F*. When this occurs, a discharge starts between *G* and *H*, the discharge immediately transfers to anode *I* which is of conventional design, and X rays are produced.

Current measurements, made by noting the voltage drop across a straight resistance wire in series with the anode of the tube, indicate that peak currents of from 1,000 to 2,000 amperes are common. Several wires of different lengths and diameters but of the same resistance are used to avoid errors caused by the self-inductance of the wire. Time of discharge and capacitance are also a measure of the current.

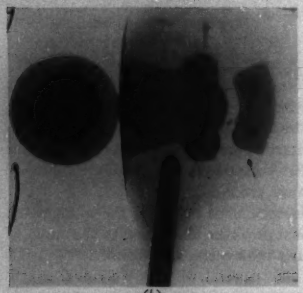
The time during which this large current passes and during which X rays are produced is of course extremely short—about one microsecond. The method used to measure this time interval is as follows:

A 0.220 Swift bullet was radiographed in free flight. The velocity of this projectile is about 4,100 feet per

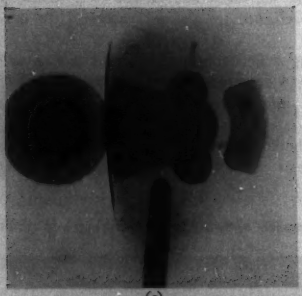
Figure 3. Here the high-speed X-ray tube has radiographed the interior of a vacuum cleaner in a millionth of a second. Flow and relative air velocity can be judged by the distribution of the particles

Figure 4. A radiograph showing a foot striking a football

(a)

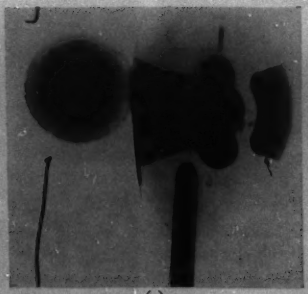


(b)

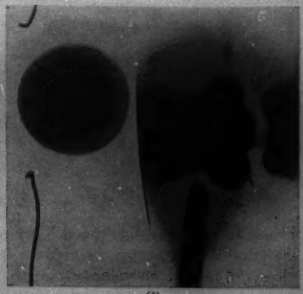


(c)

(d)



(e)



(f)

Figure 5. Radiographs showing club striking golf ball

(a) Club head approaching ball

(b) Club head makes contact with ball

(c) Core of ball partly compressed

(d) Maximum compression of core

(e) Core starts to re-expand

(f) Ball leaving club

second. Therefore, the projectile moves 1.25 millimeters in one microsecond. The amount of blurring in the radiograph of the bullet is measured and indicates the duration of the X-ray exposure. Blurring of about one millimeter with this type of projectile is common and the exposures are, therefore, about one microsecond. Calculations from the charge on the capacitor system and peak current also indicate exposure times of this order.

The field for ultrahigh-speed radiography of this type as yet has not been widely explored. The ability to record the interior change in shape of rapidly moving enclosed parts under stress, or a momentary condition in a short-time phenomena such as the striking of a golf ball or the penetration of a projectile into a wooden block, would seem to place a new tool at the service of those investigating such phenomena.

The usual method of firing the tube is to bridge switch *B* with a fine wire which is broken by the projectile, in the case of the bullet pictures. Variations of this method include a double swinging contact device of high sensitivity which was used for the golf pictures. The time interval which elapses between breaking this contact and the firing of the X-ray tube may be controlled by suitable choice of the grid-leak resistor in the thyratron circuit. The desired phase of the action also may be selected by the location of the wire with respect to the object to be radiographed. These methods are adaptable to a wide variety of conditions, and are cited merely to show the general principles involved.

Series sets of various phases in the golf ball cycle and the bullet going through wood are made up of separate X-ray shots of separate specimens, the exposures being so spaced through the cycle that a series of consecutive discrete phases is recorded. A similar series showing the passage of a charge of shot down the barrel of a shot gun has also been made.

The voltage used to produce the pictures shown here was in the region of about 120-kv peak. The wave length of the X radiation produced at this voltage is about 0.1–0.2 angstrom units, or about 10^{-9} centimeter, whereas visible light—for example, the yellow sodium line—has a wave length of about 5,800 angstrom units.

This short wave length of the X rays is responsible for their ability to penetrate objects opaque to visible light.

It also is responsible for the fact that one cannot refract or focus the X rays as one does visible light with a camera lens. For this reason, no lens is used, and the X-ray pictures are a type of shadowgraph made by placing the object between the X-ray tube and the film which is enclosed in a light-tight box known as a cassette. Under the influence of X rays, the object then casts a shadow of varying density on the film, and the picture is made.

The closer the object can be placed to the film, the better the definition obtained, other conditions remaining unchanged. For this reason, the bullet pictures made by firing close to the film show better definition than does such a picture as that of the football and foot, which were necessarily farther from the film. Efficiency of the photographic effect is increased, as in other radiographic practice, by the use of fluorescent intensifying screens, which are placed in contact with the film surface and enhance the direct effect of the X rays on the emulsion by fluorescent light.

Successful industrial applications of this system will depend largely on the thickness of the parts to be penetrated by the X rays, the degree of distortion or change to be detected, and the fineness of definition required in the picture. The exposure time of one microsecond appears to be short enough to freeze motion substantially in any application considered so far. The extent of the field to which this development will be applied will become clearer as experimental work proceeds.

Figure 6. A typical setup as used for taking a golf picture

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Effects of Corona and Spark-Over in Freon

FRANK T. DeWOLF

Gases are being used to an increasing extent as insulating media for high-voltage equipment; this article reports the results of tests of the chemical stability of Freon, which has been found most satisfactory in such applications.

PERHAPS the most effective means of increasing the compactness of high-voltage apparatus is the use of insulating media of higher dielectric strength. With the development of ultrahigh-voltage equipment[1,2] a number of gases have been examined as to their qualifications as dielectrics. Among these is Freon, CCl_2F_2, a gas having a dielectric strength about three times that of air at the same pressure[3,4,5] and a vapor pressure of 85 pounds per square inch absolute at 20 degrees centigrade. It is nonpoisonous, nonflammable, and noncorrosive under normal conditions.

However, the question of the chemical stability of Freon in the presence of corona and spark-over remained to be answered before its general use as a practical high-voltage insulating medium could be justified. When Freon was introduced into the field of refrigeration, tests showed that it breaks down chemically in the presence of a naked flame producing active decomposition products which are both corrosive and poisonous. Slight decomposition of the gas following corona and spark-over had been noted in early tests of its dielectric strength, but this phase had not been investigated thoroughly. This research was undertaken to see to what extent the disintegration of Freon by corona and spark-over limits its use as a dielectric. Further, it

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The author wishes to express his sincere appreciation for the kind help that Doctor John G. Trump of the department of electrical engineering of Massachusetts Institute of Technology extended to him during the research on which this article is based.

was planned to note the extent by which the corrosive influence of the decomposition products might be reduced by the use of some deactivator, such as lime.

In the tests comprising this research a small volume of gas, two liters in most tests, was subjected to a measured amount of corona and spark-over. Some tests were conducted to measure any change in the dielectric strength of the gas. Most of the tests, however, were concerned with the effects of the decomposition products on a specimen of metal or insulator enclosed within the chamber. Materials other than the specimen were covered with protective coatings so that the influence of the decomposition products could be concentrated on the test piece.

A d-c voltage was applied to both spark gaps and corona gaps during the various tests; however, corona activation was used primarily. A record of both ampere-hours and volt-ampere-hours was kept during the course of the 35 individual tests made. Typical figures during a corona run were: average voltage, 8.5 kv; average current, 25 microamperes; length of run, 70 hours.

A few of the tests were conducted in distilled, dried Freon. A number of others were run in air. However, most of the tests were conducted at atmospheric pressure in a mixture of Freon and undried air in a ratio of six to one, by volume. This was done because in practical applications air is nearly always present with the gas; often intentionally, so that pressures higher than the vapor pressure of Freon may be used.

A gap between two hemispherical electrodes served as the means of measuring the insulating strength of Freon. After about 40 hours of spark-over at 5.5 kv with an average current of 1.0 milliampere the dielectric strength of the gas was found to be unchanged, although it was evident that much decomposition had taken place. These results were later substantiated using corona activation. Corona and spark-over in Freon, although effective in decomposing the gas, do not materially lower its dielectric strength.

EFFECTS OF DECOMPOSITION PRODUCTS

Samples of brass, steel, copper, and aluminum were subjected to corona in air and in Freon, with and without lime present. The samples, tested individually, were inspected visually and with the aid of a spectrophotometer.

The specimens subjected to corona in Freon with lime present showed no visible effects immediately upon removal from the flasks although they darkened slightly after several days exposure to the air. With no lime present, chemical activity was evident in all cases except that of aluminum. When the flasks were opened, immediate secondary reactions took place, the corrosive films changing in appearance.

With distilled, dried Freon, the chemical attack on metals was much less severe than with Freon and air mixtures. Further, it was found that chemical corrosion of metals could be entirely prevented by the use of Lucite and Glyptal as protective films.

Even with no protective measures, however, these metals were not attacked as severely as when subjected to the same intensity and duration of corona in air alone. Thick crusty coatings were formed over the surface of the specimens which differed in color and coarseness from the thin films formed in the case of corona in Freon. The results of corona tests in air served to show the intensity of the discharge to which Freon was subjected. Since electrostatic generators of the Van de Graaff type have functioned in compressed air for long periods of time with but slight corrosion taking place, Freon, even without deactivation measures, should be suitable for such applications.

The decomposition products of Freon seemed to have no effect on rubber or Textolite. Glass was only very slightly etched after the most severe of the spark-over runs. Activated Freon greatly decreased the strength of fabric cord when no lime was present. With lime, however, cord specimens were weakened less than similar specimens subjected to corona in air.

Some surface-leakage tests were performed on disks of Textolite in Freon before and after subjection to corona. Although the surface-leakage resistivity was lowered by corona in Freon by a factor of nearly ten it was still 10^{11} ohms per centimeter. Further tests with Textolite showed that upon exposure to air the insulator resumed its original resistivity value in air. Thus, although activated Freon lowers the surface resistivity of Textolite, the decrease is neither great nor permanent.

Samples of sheet insulation were tested as to puncture strength following their subjection to corona in air and in Freon, with and without lime. The insulating strength of paper was greatly decreased in tests with no lime present; however, with lime, paper specimens were weakened less than were samples subjected to corona in air. Regardless of the presence of lime the puncture strength of varnished cambric was decreased permanently about 35 per cent by corona in Freon. Sheet rubber was apparently unaffected by corona in air or in Freon, with or without lime.

CONCLUSIONS

Although Freon may be decomposed by corona and spark-over its dielectric strength is not reduced materially nor are the decomposition products formed particularly troublesome. In general, metals and insulators are not damaged any more severely by corona in Freon than by subjection to similar activation in air. Further, it was found that adverse effects can be decreased, first, with the use of as high a purity of Freon as possible, second, by the use of some chemical deactivator placed near the corona or spark-over source, and third, by the use of protective films over vulnerable surfaces.

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A Stabilized Neon-Tube Direct-Coupled Amplifier

WILLIAM H. HUGGINS
ENROLLED STUDENT AIEE

In recent years, the application of vacuum-tube amplifiers in many fields has greatly increased. Amplifiers capable of handling frequencies in the range of from 40 to 15,000 cycles per second are common, and in the many applications where it is necessary to amplify signals of frequencies much less than 40 cycles per second, the low-frequency response has been obtained by rather elaborate compensating devices.

However, even with compensation, there exists a still lower limit of frequency, below which satisfactory amplification with allowable phase distortion cannot be obtained. One solution of the problem has been the employment of some method of direct-coupling between the amplifier stages. In addition to direct coupling, modern design dictates that the amplifier should be capable of operating from a single a-c power supply.

Figure 1 is a diagram of the circuits that have been used in the development of direct-coupled amplifiers particularly suited for use with the cathode-ray oscilloscope. This method of obtaining direct-coupled amplification uses neon tubes as the coupling elements. The necessity for an amplifying circuit which is inherently stable leads to the use of the degenerative cathode resistor. This circuit is particularly applicable where several amplifying stages must be operated from the same power source. The stabilized amplifier and its power supply are shown in figure 2.

Figure 2. Amplifier and power supply

Abstracted from a paper of the same title presented at a joint meeting of the Portland Section and the Oregon State College Branch, Portland, Ore., May 18, 1940, and subsequently awarded the AIEE national prize for Branch paper for the academic year ending June 30, 1940, which award was presented at the Institute's recent 1941 summer convention.

W. H. Huggins was a student at Oregon State College, Corvallis, when this paper was prepared; he is engaged at present on a study of aircraft-precipitation-static radio interference, being conducted at Oregon State College for the National Defense Research Committee.

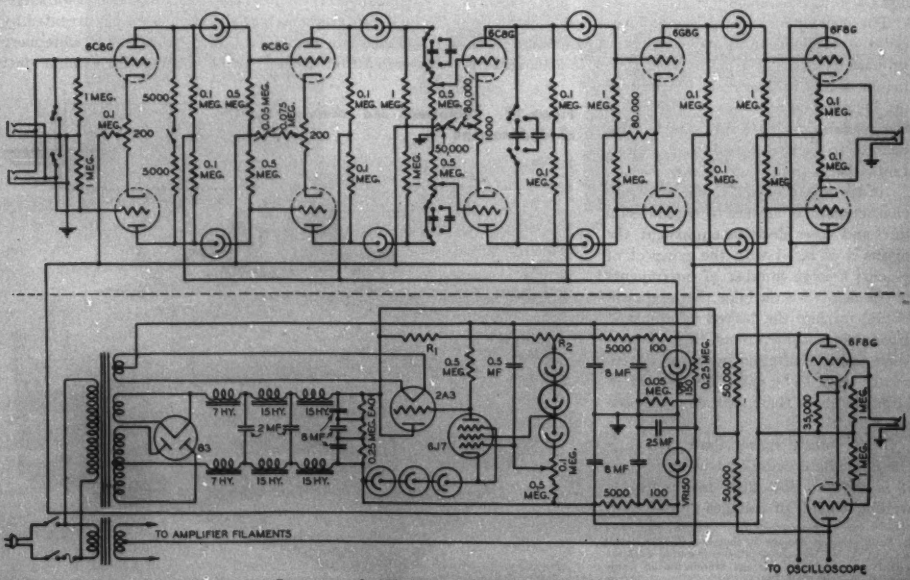


Figure 1. Stabilized gas-tube-coupled amplifier

Lightning Phenomena

II—Instruments for the Measurement of Lightning Surges

C. F. WAGNER
FELLOW AIEE

G. D. McCANN
ASSOCIATE AIEE

A number of special instruments have been developed to secure the information about lightning which utility system engineers must have if they are to devise adequate protection for the system. Such instruments are described in this second part of a series of three articles on lightning, of which part I appeared in the August issue, and part III is scheduled for next month.

OF primary importance in the lightning protection of transmission lines is a knowledge of the magnitude, duration, and wave shape of the voltage and current surges appearing on utility systems. The characteristics of the stroke itself determine the resulting surges which occur on the electrical systems. Thus it becomes desirable to have instruments capable of measuring not only the system voltages and currents, but also the properties of the stroke.

One difficulty encountered in the development of such instruments is the wide recording range both in magnitude and time that must be covered. Currents vary from a few amperes to 200,000 amperes. Portions of the wave change so rapidly that time intervals of the order of a microsecond need be measured, while at the same time the duration of the complete stroke may be longer than one second or 1,000,000 microseconds.

The element of chance is also introduced in that the point at which lightning may strike is unpredictable. The probability of a given point being struck is enhanced by height so that in some cases instruments are installed on tall objects. However, the available evidence indicates that discharges to such objects differ in important aspects from those to low objects. In order to obtain data that are truly characteristic of strokes to transmission lines and other electrical equipment, the observer is faced with the prospect of placing a large number of instruments in the field with the hope that some will obtain for him the desired information. Economic considerations thus place a very serious limitation upon the instruments, since to be practicable for use in large numbers their unit cost must be small.

Since voltage rather than current is the immediate cause of system outages it is natural that field measurements were first made of voltages produced on lines by lightning. Thus voltage-measuring instruments were developed first.

SPARK GAPS

The first attempts were made with a relatively crude device consisting of parallel gaps with different spacings. To prevent the first gap to break down from short-circuiting the others and to prevent a system outage, a relatively high resistance was placed in series with each gap. The maximum gap broken down, which was indicated by markings on a thin piece of paper, was a measure of the voltage. Peek[27] used sphere gaps and needle gaps in parallel to obtain a measure of the wave shape. A comparison of the length of gap sparked over for the two types of electrodes gave some indication of wave shape.

THE KLYDONOGRAPH

The first successful field instrument developed for surge-voltage measurements was the klydonograph, invented by J. F. Peters[28] in 1924. In 1777, Doctor G. C. Lichtenberg discovered that figures can be produced in sulphur dust

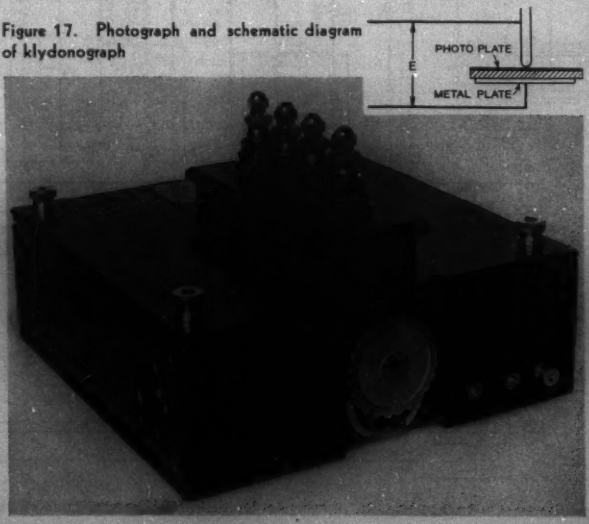


Figure 17. Photograph and schematic diagram of klydonograph

C. F. WAGNER is manager of central-station engineering and G. D. McCANN is a central-station engineer with Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

27. For all numbered references, see list at end of article.

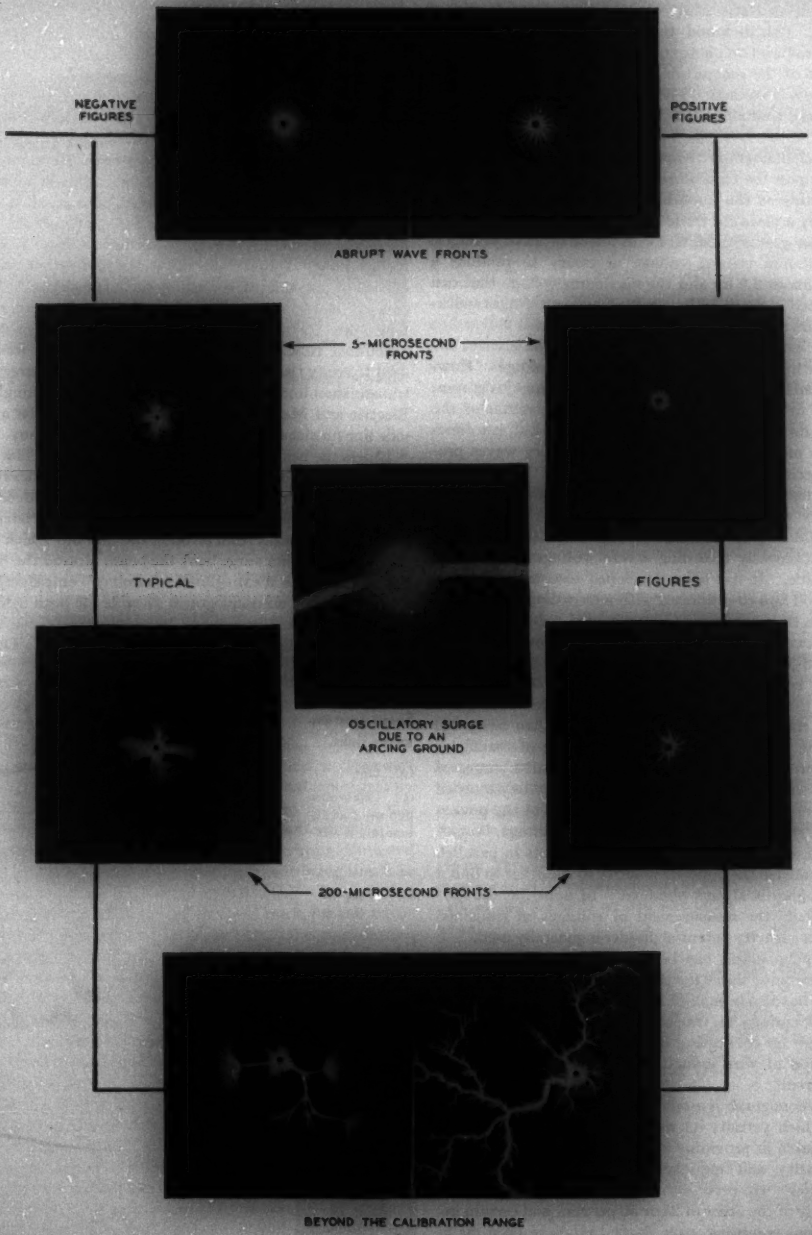


Figure 18. Typical klydonograms

by the electrostatic field of a charged electrode placed near by. Others found that Lichtenberg figures could also be produced on photographic plate. These figures are functions of the magnitude, polarity, and wave shape of the impressed voltage. The klydonograph (figure 17) employs these characteristics for the measurement of surge voltages.

The klydonograph consists of a rounded electrode bearing upon the emulsion side of a photographic film or plate resting on the smooth surface of an insulating plate backed by a plate electrode. In figure 18 are shown typical klydonograms obtained for different types of voltages. The minimum critical voltage necessary to produce a figure is about 2.0 kv and the maximum voltage that can be recorded is about 18 kv, since at higher voltages sparkover occurs and fogs the film.

For unipolarity there are characteristic differences between the figures for positive and negative voltages. However, for either polarity the radius of the figure, if it is symmetrical, or the greatest distance from the center of the figure to its outside edge, if it is unsymmetrical, is a function only of the applied voltage. Oscillatory waves produce superimposed figures for each part of the wave, enabling a distinction to be made between unidirectional and oscillatory voltages.

The klydonograph has been built with multiple elements for simultaneously recording several voltages on a transmission line. It has been developed also with a slowly moving roll film co-ordinated with a recording clock to enable more than one surge to be recorded together with its time of occurrence. In addition rapidly moving film has been used for measuring power-frequency voltages and lightning surges. A better interpretation of the character of the surge can be obtained from positive figures since for the same voltage they are more than twice the size of the negative figure, and the nature of the figure varies more with wave shape. Thus negative surges of less than twice normal line voltage cannot be recorded as they are obliterated by the positive part of the power-frequency record. To overcome this disadvantage, Foust[30] developed an instrument having two elements in parallel, one connected in the opposite polarity to the other so that a positive figure is always obtained. In applying the klydonograph to the measurement of voltages on transmission lines a capacity potential divider is generally used.

The klydonograph has been employed in conjunction with a resistance shunt for the measurement of surge currents and has also been used to measure the maximum rate of rise of current in transmission-line conductors[29] and tower legs[31] by connecting it across a resistance in series with a loop of wire inductively coupled with the main current circuit.

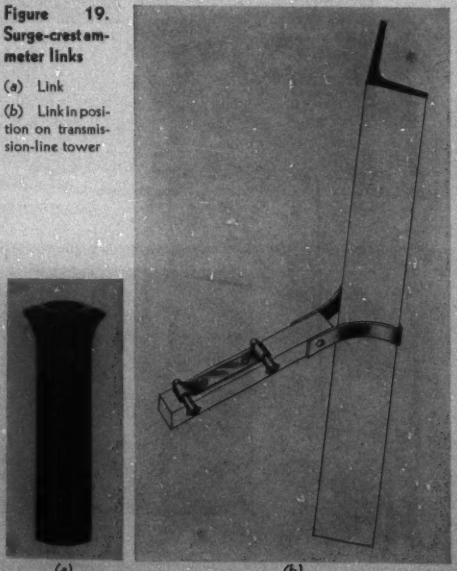
The klydonograph is a relatively simple and inexpensive device, which permits its use in large numbers. It has been valuable in providing statistical data on the magnitude, polarity, and frequency of voltage surges on transmission lines. However, its accuracy in measuring magnitude is only of the order of 25 or 50 per cent and certain interpretations regarding wave shape that have been made with it are questionable.

THE CATHODE-RAY OSCILLOGRAPH

A cathode beam consisting of a stream of electrons emitted from a "cold" cathode and accelerated in an electric field in an evacuated tube was first produced by F. Braun in 1897. Wiechect developed the concentrating coil for beam focusing and the principle of magnetic and electrostatic deflection. In 1913 Zenneck employed the principle of the cathode ray beam to record electrical phenomena. He photographed traces of the beam impinging on a fluorescent screen and deflected by a surge of a few milliseconds duration. This method of recording, however, was not suitable for surges as fast as those produced by lightning. Dufour[32] developed the first cathode-ray oscillograph capable of recording such transients. He increased the recording speed by permitting the beam to impinge directly upon photographic film placed inside the evacuated tube. An oscillograph of this type was first used to study the behavior of artificial lightning surges on a transmission line in the United States by the Westinghouse Electric and Manufacturing Company in 1926, on a five-mile line furnished by the Duquesne Light Company.

Unless the beam is prevented from striking the film until the occurrence of the phenomenon which it is desired to record, fogging of the film results. Norinder[33] overcame this difficulty by means of a special relay, which normally prevented the beam from striking the film but which upon the occurrence of a surge bent the beam around the blocking target. The Westinghouse company[34] employing this relay developed an oscillograph suitable for both field and laboratory work.

Two other schemes have been used to initiate a Dufour



(a) (b)

Figure 19. Surge-crest ammeter links

(a) Link

(b) Link in position on transmission-line tower

Figure 20. High-speed fulchronograph, showing wheel

type of oscillograph and make it suitable for lightning studies. The General Electric Company[35] developed an oscillograph in which the voltage supply to the cathode was an impulse, from a small surge generator, initiated through a triple gap by the surge to be recorded. George[36] developed a hot-cathode grid-controlled high-vacuum tube.

Oscillographs of the foregoing type employ cathode voltages of about 30 to 40 kv. Having power supplies of such high voltage and being of the pumped type to enable removal of film, they are relatively expensive and delicate in operation and require the constant attendance of an operator. These considerations greatly limit their use in the field, especially in numbers sufficient to obtain data of a statistical nature.

The Radio Corporation of America has developed a sealed-off cathode-ray oscillograph tube that permits sufficient recording speed by means of external photography of the fluorescent screen. Sufficient writing speeds by this method were made possible by its great beam intensity and the development of more sensitive photographic films and faster lenses. A laboratory oscillograph utilizing this tube has been described by Kuehni and Ramo.[37] Being sealed off, this tube lends itself readily to field work, for automatic operation. Wagner and McCann[38] with the co-operation of Ackerman developed a circuit and auxiliary device for use with this tube that permits its placement in the field without the constant attendance of an operator. It is portable and operates from a 110-volt a-c circuit. The tube is of the hot-cathode type and requires a potential of 15,000 volts to accelerate the electron beam which impinges upon a Willamite screen. The image thus produced is photographed. An auxiliary grid within the tube prevents the formation of the electron beam under normal conditions, hence fogging of the film is prevented. On the occurrence of a surge the beam is automatically initiated by the control grid and records the phenomenon.

To measure the voltages on transmission lines a capacity divider is generally used, and for surge currents a resistance shunt, the voltage across the resistance being applied to the oscillograph plates. To cover a wider current range a nonlinear shunt can be used.

PAPER GAPS

A thin piece of paper between two electrodes connected in the lead carrying the surge current has been used to obtain an indication of the magnitude of surge currents.[39,40,41] Tests with surge-generator discharges and 60-cycle currents indicate that the area of the hole produced in the paper is proportional to crest magnitude of current and is independent of wave shape. The effect of a multiple stroke, however, is questionable.

FUSIBLE WIRES

By calibrating different-sized wires connected in series and noting the largest one that fuses,[42] it is possible to obtain an approximate indication of the time integral of the square of the current. One of the first to employ this principle was professor E. C. Starr of Oregon State University, who used it to measure strokes to masts at lightning stations which he established on mountain peaks.

MAGNETIC SURGE-CREST AMMETER

The magnetic surge-crest ammeter developed by Foust and Kuehni[43] provided a simple and inexpensive instrument capable of measuring the crest magnitude and polarity of surge currents. This instrument consists of a small bundle of laminated permanent-magnet steel pieces. It is placed in an unmagnetized condition in the vicinity of a conductor whose current it is desired to measure. The remanent magnetism produced in the steel is a function of the magnitude of the current producing it for unidirectional surges. A special instrument measures the remanent magnetism and is calibrated directly in terms of the original magnetizing current. The polarity of the surge is indicated by the direction of magnetization. This instrument has been used extensively both in the United States and abroad to measure currents in direct strokes; in transmission-line tower legs, ground wires, and phase conductors; in counterpoise conductors and in ground leads of arresters.

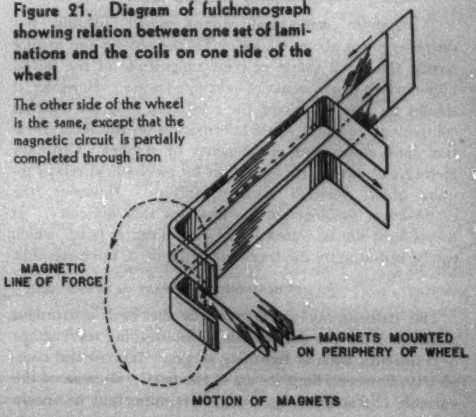

The other side of the wheel is the same, except that the magnetic circuit is partially completed through iron
MAGNETIC LINE OF FORCE
MAGNETS MOUNTED ON PERIPHERY OF WHEEL
MOTION OF MAGNETS

Figure 21. Diagram of fulchronograph showing relation between one set of laminations and the coils on one side of the wheel

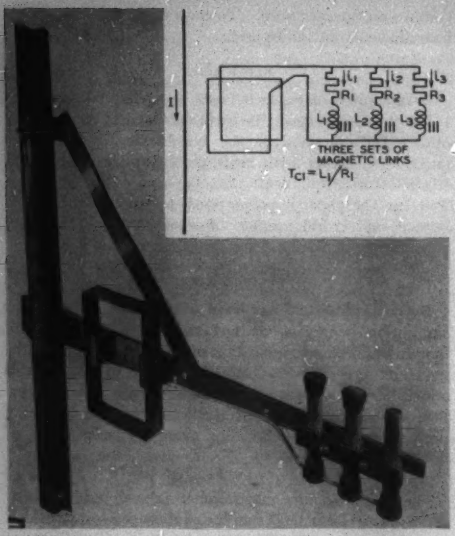


Figure 22. Magnetic surge-front recorder

The magnetic links are usually placed in brackets as shown in figure 19, fastened to the conductor so that their axes coincide with the normal direction of the magnetic lines of force. Several links placed at different distances from the conductor commonly are used to cover a wider range of currents and also to distinguish between unipolarity and oscillatory surges. These instruments being cheap and simple, thousands of them have been used throughout the United States and have provided valuable information relating to lightning currents.

CRATER-LAMP OSCILLOGRAPH

A magnetic oscillograph cannot record faithfully frequencies much above 10,000 cycles per second and cannot record the wave shape or crest magnitude of the initial high-current components of lightning surges. However, it should be able to record the relatively long low-current component and give some information on the total duration and number of components of strokes. Ordinary methods of automatic operation by mechanical relays require about one-half cycle to initiate. However, the crater-lamp oscillograph[44] overcomes this difficulty. It uses a light source consisting of a neon crater lamp, which can be initiated by the transient in about 20 microseconds.

FULCHRONOGRAPH

The cathode-ray oscillograph is the best instrument available from the standpoint of determining wave shape of transients, such as lightning surges. Its cost and complexity, however, limit its use in the field. Because of the variable character of lightning, it is important to obtain sufficient data to determine the statistical nature of its properties. The klydonograph and surge-crest ammeter have provided data of this type on the magnitude and polarity of surge voltages and currents. The number of components, wave shape, and duration of surges are of even more importance, however, and it was with the view of gathering data on these properties of surges that the Westinghouse Electric and Manufacturing Company[45] developed a number of new recording instruments. The most important of these is the fulchronograph,* a device capable of measuring the wave shape and duration of the tail of current surges, but cheap enough, and simple enough in its operation to be used in large quantities in the field.

The essential part of the fulchronograph is a slotted aluminum rotating wheel. In a "high-speed" fulchronograph, figure 20, the wheel turns at 3,450 rpm, and in the "slow-speed", with the speed of approximately 60 rpm. In the rim of each are 408 laminations of permanent magnet steel nine mils thick, projecting from each side. The laminations pass between narrow coils (see figure 21) through which flows the current to be measured. As a particular set of laminations spans the gap between the coils, they are subjected to a radial magnetizing force proportional to the current at that instant. By measuring the retentivity or residual flux in the laminations it is possible to reconstruct a graph of the current as a function of time. The device functions in a manner similar to the surge-crest ammeter except that time has been introduced by the rotation of the wheel.

By placing a high-speed and a low-speed fulchronograph together in series and running them continuously, greater wave detail and a longer period of time can be covered than by the use of either one separately. The high-speed unit in one revolution divides 17,000 microseconds into 43-microsecond intervals, the low-speed unit in one revolution divides 1 second into 1/400 second intervals. Multiple-stroke discharges rarely last longer than one second, or have time intervals between strokes of more than 0.5 second. These facts make it possible with the data provided by the two wheels to resolve a surge into its multiple components and to obtain the wave magnitude and shape of each.

MAGNETIC SURGE-FRONT RECORDER

The principal disadvantage of the fulchronograph is its inability to measure the high rates of rise of the front of the waves. Devices for measuring the maximum rate of rise have been available for some time. As mentioned previously, the klydonograph can be used to indicate the maximum rate of rise on the front of lightning-current surges. Probably of greater importance than the maximum rate of rise is the average rate of rise, such as can be defined by a straight line drawn through the 10 per cent and 90 per cent of crest value.

The magnetic surge-front recorder which, with a schematic diagram, is shown in figure 22 is a device for recording this property of lightning currents. It consists of

*This name was obtained as a combination of the Latin word *fulmen*, meaning lightning, and the Greek words *chronos*, meaning time, and *graphein*, meaning to write.

three circuits containing resistance and inductance having different time constants. They are connected across an inductance carrying the main surge current or a loop inductively coupled with the circuit carrying the main surge current. Magnetic links placed within the field of the inductors of these three circuits serve to record their maximum currents i_{max}. The introduction of an appreciable time constant T_c into these circuits prevents the currents in them from responding to instantaneous changes in the main current, thus substantially eliminating the effect of high-frequency oscillations in the front of the wave. If these resistors were not present, the current in the auxiliary coils at all times would be proportional to the rate of change of the main surge current and the maximum current in them would be proportional to the maximum rate of rise of current on the front of the main surge.

When inductance is added to the auxiliary circuits, the maximum current in any one of them is proportional to the average rate of rise of the main surge current over a definite range. Three of these circuits are adequate to cover the desired range of time to reach crest.

MAGNETIC SURGE INTEGRATOR

The magnetic surge integrator is a relatively simple and inexpensive device for recording the total charge or the integral of the current in a lightning surge. It consists essentially, as shown by the schematic diagram of figure 23*a*, of a noninductive shunt that carries the main surge current, and across which an inductor is connected. Neglecting the resistance of the inductor, its current at any instant is equal to the time integral of the main surge current, and, if the surge is nonoscillatory, the final maximum value of this current is the total integral of the main surge current. To cover a wide range, three magnetic links are placed at different points within the magnetic field produced by the coil. The magnetic field that magnetizes the links is a function of the coil current. Thus from a measurement of the remanent magnetism in the links a record of the total charge in the surge is obtained. The effect of the resistance of the coil is to limit the time for which the response is an accurate measure of the integral of surge current. If two coils having different time constants are used it is possible, in addition to measuring the charge, to form some idea of the wave shape. The two time constants are adjusted so that one coil can measure accurately up to 10,000 microseconds (figure 23*b*) and the other up to 300 microseconds. This type of integrator forms, with the magnetic surge-front recorder and surge-crest ammeter, a good, inexpensive combination, especially where power is not available.

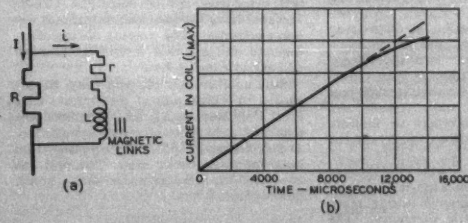


Figure 23. Magnetic surge integrator

(*a*) Schematic diagram
(*b*) Response curve

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Highway Lighting and Traffic Capacity. Not only increased safety but added capacity for traffic is conferred on highways by adequate lighting. This seems proved by a report by W. P. Walker, assistant highway economist of the Public Roads Administration, published in "Highway Research Abstracts", December 1940.

On a well-lighted highway, it was found, drivers seized opportunities for safely passing a slower vehicle approximately as often as by daylight, but with the highway unlighted only two-thirds as many opportunities were utilized. Consequently the tendency for traffic to collect behind a slowly moving vehicle was increased and road capacity thus was reduced.

On the unlighted highway drivers tended to edge over toward the center of the road, thus reducing its effective width. Adequate lighting, making clear the position of the curb, kept the cars in their normal daylight positions.

"Illumination Note" contributed for the AIEE committee on production and application of light by L. A Hawkins (A'03, M'13) executive engineer, research laboratory, General Electric Company, Schenectady, N. Y.

Institute Activities

South West District Meeting Will Be Held at St. Louis, October 8–10

A DIVERSIFIED PROGRAM has been arranged for the South West District meeting to be held at St. Louis, Mo., October 8–10, 1941. Seven technical sessions, a technical conference, and a general session are planned, in addition to various trips, sports, and entertainment. Meeting headquarters will be at the Coronado Hotel, which is centrally located and specializes in convention accommodations.

TRIPS

Three types of trip—sight-seeing, inspection, and special—are planned. Advance registration for the sight-seeing trips is desirable although not essential. All industrial trips are limited to United States citizens and, where indicated, to AIEE members. The special trips will be made only if sufficient numbers are interested. They will be scheduled at times to suit the majorities. Because of National Defense regulations industrial trips require registration in advance of October 1. A card for this purpose will be sent to all members of the South West District and near-by territory.

Sight-Seeing Trips. A general tour of St. Louis will be made on Wednesday afternoon to see the New Cathedral, Lindbergh trophies, famous Art Hill, zoo and bear pits, Jewel Box, Aloe Plaza and Milles Fountain, Memorial Plaza and Municipal and Federal Building Group, site of new Jefferson Memorial (Riverfront) Plaza, Christ Church Cathedral, St. Louis University, and many other points of interest.

Another special-interest tour, especially for women although men also are invited, will be made on Thursday morning to the Art Museum, world-famous Shaw's Garden, the home of Eugene Field, and the Old Cathedral, built in 1840.

Inspection Trips. Three trips have been arranged for Thursday afternoon. Members may choose to visit power plants, Washington University, or the Beaumont telephone office. Each of these trips includes a visit to the Anheuser-Busch brewery.

One trip includes the new Venice and Cahokia power plants of the Union Electric Company. The new Venice power plant is now under construction and will have an ultimate capacity of 400,000 kw. Two 40,000-kw turbogenerators and two pulverized fuel boilers are to be placed in service late this year. The Cahokia power plant has 6 turbogenerators and 24 pulverized fuel boilers, total capacity 300,000 kw. New fly-ash precipitators are in operation on one of six stacks. This trip is limited to AIEE members.

The Anheuser-Busch brewery, included on each of the three trips, had an estimated 1941 production of 3,000,000 barrels of beer. Corn products, baker's yeast, and refrigerated cabinets are also manufactured. The power plant, brew house, bottling plant, and the reception room may be visited.

A second trip will be arranged to Washington University to see the new Cyclotron and make a tour of the other buildings. The Cyclotron is the second largest in the country, with an 80-ton electromagnet, 12-ton cooling coils, and a radio-frequency oscillator of 50 kw at a frequency of 11,000,000 cycles. The schools of architecture, fine arts, liberal arts, engineering, law, business and public administration and graduate studies are on a beautiful campus. Women guests are invited on this trip.

The third trip offered will be to the Beaumont telephone office, where the toll exchange of the Southwestern Bell Telephone Company and the long lines department of the American Telephone and Telegraph Company are located. Here may be seen operators at a 250-position long-distance switchboard, wire-photograph transmission equipment, telephone carrier equipment, teletypewriter switchboard, telegraph composite equipment, radio-transmission switching, and other testing equipment.

Three trips also are planned for Friday afternoon. The first consists of a radio tour, on which women also are invited. The second will be taken to a substation and a transformer manufacturing plant, and the third will be a tour of the a-c network of the Union Electric Company. The last two trips are limited to AIEE members.

On the radio tour transmitting station KWK, broadcasting station KMOX of the Columbia Broadcasting System studios, and frequency modulation station and radio dispatcher's room of the St. Louis Public Service Company will be visited. Station KWK operates on 5,000 watts at a frequency of 1,370 kilocycles with a half-wave vertical antenna. The 50,000-watt station KMOX operates at a frequency of 1,110 kilocycles and is the point of origin for many chain programs. This station has modern sound and technical equipment for producing and receiving major chain programs. The frequency-modulation station is a two-way system for street-railway and bus dispatching and communication with supervisors' cars and emergency trucks. This station consists of a 250-watt transmitter, 250-foot tower, remote-control radio console and street-car headway recorders to indicate passage of cars at various points on the system.

The second trip will be to the Page Avenue substation of the Union Electric Company and the transformer manufacturing plant of the Moloney Electric Company. The substation is an interconnection point between 25-cycle and 60-cycle systems and is an important switching center for a major transmission loop. Three 20,000-kw variable-ratio automatically controlled frequency changers, 416,500 kva of transformer capacity are installed. In the plant of the Moloney Electric Company many classes of transformers are manufactured, ranging from power sizes of 30,000 kva, 161,000 volts to the distribution sizes. Testing equipment includes a 2,500,000-volt surge generator.

On the tour of the new a-c network system of the Union Electric Company may be seen 500-, 750-, and 1,000-kva, 13,800+120–208-volt network units, including network protectors and primary three-way grounding switches; specially designed network relay test board; miniature of complete system, comprising network calculating board; distribution trouble dispatching office; and system load dispatching office.

Special Trips. If a sufficient number are interested, the following trips may be arranged at a time to suit the majority.

A trip to inspect the newest model PCC street cars of the St. Louis Public Service Company may be arranged. The general shops are equipped with new inspection bays, which have specially designed overhead and pit lighting. A special motor-generator set also is employed to make possible relay and line-breaker settings over a wide range.

A trip also may be arranged to inspect three distribution substations of the Union Electric Company. The Tenth Street substation is one of the largest of the company's d-c substations, automatically operated, with a capacity of 7,850 kw. The Fifteenth Street substation is the newest d-c substation, equipped with an 1,800-kw motor-generator set and a 2,250-kw rotary converter, unattended. The Carondelet substation supplies the 4,500-volt distribution system and is equipped with two 13,333-kva 33/4.5-kv transformers, five 3,900-kva regulated outgoing feeders. The equipment of this station is of unusual steel cubicle design. If arranged, this trip will be limited to AIEE members.

Another possible trip may be arranged to inspect the electric-arc furnaces of the St. Louis Steel Casting Company, where 800- and 1,500-kva, 13-kv, three-phase "Lectromelt" furnaces are in operation. These furnaces have automatically operated carbon electrodes. The pouring of steel castings, as well as other interesting foundry operations, may be seen.

Still another possible trip may be arranged to a steel mill of the Granite City Steel Company, which has continuous hot and cold strip mills of recent installation. D-c drives and control are supplied from large motor-generator sets. The mill has two 7,500-kw turbogenerators and a steam power plant.

ENTERTAINMENT

Wednesday afternoon a bridge party for women guests will be given at the Park Plaza Hotel. After bridge there will be a

South West District Meeting Program

Wednesday, October 8

9:00 a.m. Registration

10:00 a.m. General Session

Opening address of welcome. J. L. Hamilton, vice-president, South West District

Address, "Electric Utilities' Part in National Defense." E. T. Gushee, executive vice-president, Union Electric Company of Missouri

Address, "St. Louis a Clean Place to Live." Raymond Tucker, past director of smoke abatement

2:00 p.m. Selected Subjects

41-152. A Novel Reclosing Relay. P. O. Bobo, Oklahoma Gas and Electric Company

41-153. Symmetrical Nomenclature of Three-Phase Circuits. Bryce Brady, Oklahoma Gas and Electric Company

41-141. Lightning Strokes in Field and Laboratory—III. P. L. Bellaschi, Westinghouse Electric and Manufacturing Company

2:00 p.m. Transformers

DP.* Trends in Design of High-Voltage Power Transformers. W. C. Sealey, Allis-Chalmers Manufacturing Company

DP.* Modern Load-Ratio Control Transformers. F. W. Bush, Allis-Chalmers Manufacturing Company

DP.* Calculation of Transformer Temperatures Under Overloads. R. H. Jones, Jr., Moloney Electric Company

DP.* Current Distribution and Transformer Winding Containing a Short Circuit. H. Weichsel and W. L. J. F. Godin, Wagner Electric Corporation

41-159. High-Pressure Gas as a Dielectric. G. C. Nonken, General Electric Company

Thursday, October 9

9:30 a.m. Electrical Machinery and Power Generation

41-160-ACO.** 160,000 Kw at Venice Plant Number 2, Union Electric Company of Illinois. R. R. Wisner, Stone and Webster Engineering Corporation, and Stanley Stokes, Union Electric Company of Missouri

41-158. A Turbine Governor Performance Analyzer. W. O. Osbon, Westinghouse Electric and Manufacturing Company

41-161-ACO.** Experimental and Operating Data on Vibration and Sound Level in Two-Pole Generators. J. W. Batchelor and H. E. Criner, Westinghouse Electric and Manufacturing Company

●PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in this program may be obtained as noted in the following paragraphs.

●ABSTRACTS of papers appear on pages 446–8 of this issue, pages 406–07 of the August 1941 issue, and for paper 41-105 page 290 of the June 1940 issue of Electrical Engineering.

●PRICES and instructions for securing advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members as an adequate supply of each paper at the convention cannot be assured. Only numbered papers are available in pamphlet form.

●COUPON books in $5.00 denominations are available for those who may wish this convenient form of remittance.

●ALL PAPERS regularly approved by the technical program committee ultimately will be published in Transactions; many will appear also in Electrical Engineering.

DP.* Methods of Obtaining Variable Speeds. A. F. Hartung, Burns and McDonnell Engineering Company

9:30 a.m. Transmission and Distribution

DP.* Application of Telemetering and Automatic Tie-Line Load Control to Interconnected System Operation. M. J. Thrasher, Texas Power and Light Company

DP.* Design and Application of Fuse Links for Use in Fiber Tube Cut-Outs. L. L. Crump, James R. Kearney Corporation

41-151-ACO.** Design Features of a New High-Capacity Network Protector. J. W. Seaman and R. W. Smith, General Electric Company

Friday, October 10

9:30 a.m. Communication and Radio

DP.* How Crosstalk Affects Toll-Cable Installation Methods. A. G. Chapman, Bell Telephone Laboratories, Inc.

41-149. The Communication Facilities of the United States Forest Service. A. G. Simson, Forest Service, U. S. Department of Agriculture

DP.* Conductor Radio, an Innovation in Nonreturn Circuits. J. D. Browder, Oklahoma Gas and Electric Company

41-105. Diode Rectifying Circuits With Capacitance Filters. D. L. Waidelich, University of Missouri

DP.* Selenium Rectifiers and Principles of Their Design. J. E. Yarmack, International Telephone and Radio Manufacturing Corporation

9:30 a.m. Motors

41-154. The Inherent Overheating Protection of Single-Phase Motors. C. P. Potter, Wagner Electric Corporation

41-157. The Equal-Volt-Ampere Method of Designing Capacitor Motors. P. H. Trickey, Riehl Manufacturing Company

41-162. The Apparent Impedance Method of Calculating Single Phase Motor Performance. W. J. Morrill, General Electric Company

2:00 p.m. Conference on Motors

CP.† Report on General Principles for Rating of Electrical Apparatus for Short Time, Intermittent or Varying Duty. P. L. Alger, chairman, AIEE Co-ordinating Committee number 4, Basic Principles for Rating of Electrical Machinery and Apparatus.

CP.† Development of Polyphase Rotors. Martin Schiff, Century Electric Company

CP.† Purifying and Cleaning of Hermetic Motor Parts. A. C. Dickson, Emerson Electric Manufacturing Company

2:00 p.m. Electrical Instruments

41-156. A Cathode-Ray Method of Wave Analysis. V. O. Johnson, Westinghouse Electric and Manufacturing Company

41-155. A Cathode-Ray Oscillograph With Rotating Drum Camera. E. G. Downie, General Electric Company

41-143. The Modern A-C Network Calculator. W. W. Parker, Westinghouse Electric and Manufacturing Company

*DP: District paper, for which no advance copies are available; not intended for publication in Transactions.

**ACO: Advance copies only available; not intended for publication in Transactions.

†CP: Conference paper; no advance copies are available; not intended for publication in Transactions.

dinner and floor show for women only.

Wednesday evening from 7:30 to 9:30 P.M. there will be a smoker for the men in the Coronado Hotel, with a four-piece orchestra and other entertainment. Tickets are $1.50 each; for students, $1.00.

Thursday noon a luncheon will be arranged for all those attending the meeting. Talks will be given by President D. C. Prince and National Secretary H. H. Henline. Doctor William McClellan, a past president of the AIEE, will preside.

Thursday evening a banquet and dance will be held. There will be music during the dinner, and other entertainment. Students who do not desire to attend the dinner are invited to attend the dance without cost.

SPORTS

St. Louis has a number of golf courses and the committee will make arrangements upon request for any who wish to play. Because of the limited time of the meeting there will be no tournament. The committee also will be glad to direct anyone to the many bowling alleys which are available.

On the Saturday following the meeting there will be a football game, Oklahoma A. and M. College against Washington University at the Washington University stadium in St. Louis. Arrangements will be made for special rates to AIEE members.

MEETINGS

The executive committee of the South West District will meet on Thursday, October 9, at 2:00 P.M. A meeting of Branch Counselors also will be scheduled later by Chairman R. S. Glasgow.

COMMITTEES

District meeting committee members are:

J. L. Hamilton, vice-president, South West District; L. L. Crump, secretary, South West District. L. O. Campbell, F. A. Decker, R. S. Glasgow, R. B. Gow, J. S. Johnson, R. G. Meyerand, H. R. Pearson, and W. B. Stephenson.

Chairmen of subcommittees are:

G. A. Waters, *general committee;* R. S. Glasgow, *student activities;* F. A. Cooper, *meetings and papers;* Lee Washington, *hotels and registration;* L. L. Crump, *publicity and attendance;* O. J. Rotty, *inspection and transportation;* C. B. Hall, *finance;* B. S. Rehagen, *entertainment;* Mrs. L. O. Campbell, *women's entertainment.*

Additional 1940 District Prize

District 2

Prize for Branch paper was awarded to George J. Thaler for his paper "Characteristics of Fluorescent Lamps," presented at a student meeting of the Maryland Section, held at The Johns Hopkins University, Baltimore, Md., April 29, 1940.

National • • • •

AIEE Committee Changes

One Institute general committee has been abolished and two others merged into a third by recent action of the AIEE board of directors. The committees on economic status of the engineer and on legislation affecting the engineering profession have been consolidated into the committee on Institute policy, which will carry on their activities through subcommittees. The committee on Columbia University scholarships has been abolished, because funds for the scholarships are not available.

Board of Directors Meets

The regular meeting of the AIEE board of directors was held at Institute headquarters, New York, N. Y., August 8, 1941.

Upon recommendation of the publication committee, authorization was given for issuing as a special Institute publication, on a self-supporting basis, a "Bibliography on Circuit Breakers, Switches, and Fuses, 1928–40," which had been prepared by the committee on protective devices.

The appointment by the president of committees of the Institute for the administrative year beginning August 1, 1941, was announced (for complete list of officers and committees for 1941–42 see pages 453–7).

It was voted to consolidate the committee on economic status of the engineer and the committee on legislation affecting the engineering profession into the Institute Policy committee, which will carry on their various activities through the necessary subcommittees.

Because the scholarships will not be available for the coming year at least, it was decided to abolish the committee on Columbia University scholarships.

In accordance with recommendations of the standards committee, the board approved the following:

Revised American Standard for Letter Symbols for Hydraulics, Z10b

Revised American Standard for Letter Symbols for Mechanics of Solid Bodies

Revised American Standard for Illuminating Engineering Nomenclature and Photometric Standards

A report by W. S. Mallory, secretary, of the activities, accomplishments, and dissolution of The Thomas Alva Edison Foundation (on which the Institute had four representatives) was presented. The national secretary was directed to acknowledge the report, and to transmit to W. S. Barstow, president of the Foundation, the Institute's appreciation of his outstanding contributions to the activities of the Foundation.

The following appointments by the president, upon recommendation of the standards committee, were approved:

H. M. Turner as AIEE representative on and chairman of the Sectional Committee Z10, Letter Symbols and Abbreviations for Science and Engineering

L. V. Winchester as AIEE representative on a proposed Sectional Committee on Safety Code for Quarry Operation

Various representatives of the Institute on other bodies were appointed for the year beginning August 1, 1941; also the following were reappointed:

J. F. Fairman on the Engineers' Council for Professional Development, for the term of three years beginning in October 1941

W. I. Slichter on the Library Board of United Engineering Trustees, Inc., for the four-year term beginning in October 1941

F. Malcolm Farmer on the Board of Trustees of United Engineering Trustees, Inc., for the 4-year term beginning in October 1941

L. W. Chubb on the Research Procedure Committee of The Engineering Foundation for the term of one year beginning in October 1941

Local honorary secretaries of the Institute were reappointed for the two-year term beginning August 1, 1941, as follows:

A. P. M. Fleming for England
P. H. Powell for New Zealand
A. F. Enstrom for Sweden
Richard H. Bowles for Brazil

Appointment by the president of R. N. Conwell, I. Melville Stein, and S. B. Williams as members of the Lamme Medal committee for the three-year term beginning August 1, 1941, was confirmed.

The board confirmed the appointment by the president of N. E. Funk as chairman for the year beginning August 1, 1941, and J. T. Barron, R. E. Doherty, and J. V. B. Duer as members of the Edison Medal committee for the term of five years. From its own membership, the board elected M. S. Coover, Mark Eldredge, and R. W. Sorensen as members of the Edison Medal committee for the two-year term beginning August 1, 1941.

The board confirmed the appointment by the president of W. F. Davidson and D. F. Miner as members of the Charles LeGeyt Fortescue Fellowship committee for the term of three years beginning August 1, 1941.

Other actions taken by the board included the following:

Minutes of the meeting of the board of directors held on June 18, 1941, were approved.

Recommendations adopted by the board of directors at its meeting held on July 10, 1941, were presented and approved.

Upon recommendation of the board of examiners, the following actions were taken: 1 applicant was elected and 1 was transferred to the grade of Fellow; 52 applicants were transferred and 24 were elected to the grade of Member; 182 applicants were elected to the grade of Associate; 30 Students were enrolled.

Expenditures in July, amounting to $27,366.50, were reported by the finance committee and approved.

Those present were:

President—David C. Prince, Schenectady, N. Y.

Past President—F. Malcolm Farmer, New York, N. Y.

Vice-Presidents—J. L. Hamilton, St. Louis, Mo.; N. S. Hibshman, Bethlehem, Pa.; J. Elmer Hobley, Alcoa, Tenn.; Everett S. Lee, Schenectady, N. Y.; C. A. Price, Hamilton, Ont.; Walter C. Smith, San Francisco, Calif.; A. LeRoy Taylor, Salt Lake City, Utah.

Directors—M. S. Coover, Ames, Iowa; Lester R. Gamble, Spokane, Wash.; T. G. LeClair, Chicago, Ill.; L. R. Mapes, Chicago, Ill.; Fred R. Maxwell, Jr., Pensacola, Fla.; W. B. Morton, Philadelphia, Pa.; H. S. Osborne, New York, N. Y.; R. G. Warner, New Haven, Conn.

National Treasurer—W. I. Slichter, Schenectady, N. Y.

National Secretary—H. H. Henline, New York, N. Y.

Future AIEE Meetings

South West District Meeting
St. Louis, Mo., October 8–10, 1941

Southern District Meeting
New Orleans, La., December 3–5, 1941

Winter Convention
New York, N. Y., January 26–30, 1942

Section • • • •

New York Group to Sponsor Lectures on Nonlinear Theory

During the winter of 1941–42, the basic science group of the AIEE New York Section will offer a series of lectures on nonlinear circuit theory. One object of these lectures is to present to the electrical engineer the more important analytical and graphical methods of solving nonlinear equations used in both the power and communication fields. Another object is to stimulate further interest and research on the subject. Some of the lecturers may introduce unpublished material of interest. The lectures are to be simplified and coordinated on the assumption that the listeners have had no special mathematical training.

This new series will supplement that sponsored by the basic science group in 1940–41. Given as a symposium on advanced mathematics, those five lectures proved to be of sufficient general interest that the lecturers were asked to contribute articles on their several topics to ELECTRICAL ENGINEERING. The first article "Heaviside's Direct Operational Calculus" is scheduled to appear in an early issue. Other articles on integration in the complex plane, Laplacian transformation, Fourier integrals, and traveling waves on transmission lines will appear in subsequent issues in their original order of presentation. At the completion of publication of the series, a composite reprint booklet is expected to be issued at a nominal price for the convenience of all who may be especially interested in the subject.

Abstracts • • •

TECHNICAL PAPERS are previewed in this section as they become available in advance pamphlet form. Copies may be obtained by mail by remitting price indicated to the AIEE order department, 33 West 39th Street, New York, N. Y.; or at five cents less per copy if purchased at AIEE headquarters or at AIEE convention or District-meeting registration desks.

The papers previewed in this issue will be presented at the AIEE South West District meeting, St. Louis, Mo., October 8–10, 1941.

Basic Sciences

41-159—High-Pressure Gas as a Dielectric; *Gordon C. Nonken (A'36). 15 cents by mail.* Impulse and 60-cycle breakdown strength of sphere gaps, rod gaps, and of solid fluid built-up samples are reported in this paper. The tests were made in nitrogen up to 200 pounds per square inch gauge pressure and in Freon up to 70 pounds per

square inch gauge pressure. Dielectric strength values were compared with the breakdown of transformer oil under similar conditions. Gap conditions were found for which the 60-cycle breakdown of a gas was twice its impulse strength. Whereas gases under pressure have greater 60-cycle breakdown strength than transformer oil under some conditions, under the same conditions the oil has the greater impulse-breakdown strength.

Electrical Machinery

41-154—The Inherent Overheating Protection of Single-Phase Motors; *C. P. Potter (F'29). 15 cents by mail.* "Inherent overheating protective devices," ordinarily known as "motor protectors," are selected for application on single-phase motors in accordance with the requirements of the Underwriters' Laboratories (Industrial Control Equipment, appendix pages 26A, 26B, 26C, and 26D). The tests specified by the Underwriters' Laboratories are relatively simple and are made at normal frequency, at approximately normal voltage, at ordinary room temperatures, and with free motor ventilation. This paper reports the results of special tests which were made at abnormal voltages, abnormal frequencies, high ambient temperatures, and with restricted ventilation, to determine whether a single-phase motor equipped with a protector which meets the Underwriters' tests can have hazardous winding temperatures under any operating conditions. The author arrived at the conclusion "that inherent overheating protective devices mounted inside fractional-horsepower single-phase motors completely protect them against all abnormal operating conditions."

41-157—The Equal-Volt-Ampere Method of Designing Capacitor Motors; *P. H. Trickey (M'36). 15 cents by mail.* An improved method of designing capacitor motors has been devised, based on a method developed by the author and described in a previous paper, "The Design of Capacitor Motors for Balanced Operation" (*AIEE Trans., vol. 51, 1932, p. 780–5*). The new method has the same general advantages of simplicity and ease of performance calculation as the "balanced" method, but results in a motor with a less expensive capacitor. It consists in calculating a "balanced" motor then modifying the design in a certain specified manner which does not materially affect the performance. Curves are given showing how departure from the "balance point" by the "equal-volt-ampere" method affects the no-load, full-load, and starting performance, and the maximum and locked rotor torques.

41-161–ACO.—Experimental and Operating Data on Vibration and Sound Level in Two-Pole Generators; *J. W. Batchelor (A'38) and H. E. Criner. 15 cents by mail.* Double-frequency vibration of a two-pole rotor is caused by unequal rigidity about the pole center line, and the axis perpendicular to this center line. In addition, the air-gap flux is responsible for unequal magnetic attraction along the two axes, causing the stator to distort. The distorted stator takes the form of an ellipse which rotates with the field, and causes the 120-cycle vibration at normal running speed. Correction for rotor vibration consists of cutting transverse slots in the poles to equalize the rigidity. The effect of the stator vibration is minimized by isolating the core. This paper reviews the methods used in reducing double-frequency vibration and sound level at points exterior to the generator frame. Data taken in the shop and field on comparable machines show how effective the methods are in obtaining the desired reduction.

41-162—The Apparent-Impedance Method of Calculating Single-Phase Motor Performance; *Wayne J. Morrill. 15 cents by mail.* In the past several years there have been offered a number of calculation methods to be used in connection with predetermining the performance of single-phase induction motors. While such methods are usually based upon either the cross-field or the revolving-field theory, they differ from each other according to individual preferences. In the present paper there is proposed a method which seems to be convenient and simple, and which, because of symmetry, involves a minimum of charts in carrying out the necessary calculations. The method is proposed because it has been used in one design department for a number of years and found to be very satisfactory as a practical method.

Instruments and Measurements

41-155—A Cathode-Ray Oscillograph With Rotating-Drum Camera; *E. G. Downie (A'35). 15 cents by mail.* The study of operation of certain high-voltage, low-current equipment, such as the luminous-tube transformer, requires the use of the cathode-ray oscillograph. It is desirable to record on film recurring or nonrecurring waves viewed on the cathode-ray screen, and to compare phase angles of any number of current or voltage waves. A cathode-ray oscillograph and rotating-drum camera have been developed to meet these needs. Images on the short persistence screen are recorded on 35 mm film in a rotating-drum camera focused on the screen and driven by a synchronous motor. A reference point of time or phase position is provided on successive exposures by a small, very sharp voltage peak, occurring each half-cycle, superimposed on the original wave. A convenient spring drive is also provided on the camera drum for exposures at various film speeds, with a single revolution of the drum.

41-156—A Cathode-Ray Method of Wave Analysis; *Vincent O. Johnson (A'39). 15 cents by mail.* Complex periodic functions, when transformed into corresponding voltage waves, may be analyzed with the use of a cathode-ray oscillograph. The complex wave is represented upon the fluorescent screen of the cathode-ray tube by a vertical displacement at the same time that a sinusoidal horizontal oscillation exists. If the frequency of the sinusoidal oscillation bears an integral relation to the fundamental frequency of the complex wave, a Lissajous figure is viewed on the screen. The areas of these Lissajous figures are directly related to the coefficients of the Fourier series for the complex wave. The area is determined by measuring a photograph of the figure, using a polar planimeter. The method is based on the theory developed by L. W. Chubb in connection with the Chubb Polar Analyzer.

Power Generation

41-158—A Turbine-Governor-Performance Analyzer; *W. O. Obson (M'41). 15 cents by mail.* Numerous papers and discussions at recent meetings of the AIEE and ASME have revealed an urgent need for means of measuring turbine-governor performance. Instruments for making such measurements have been developed and are described in detail. These include means for measuring and simultaneously recording the following four quantities: (1) generator load; (2) turbine speed in terms of generator or system frequency; (3) turbine steam-valve travel; and (4) various hydraulic pressures within the governor. The instruments are characterized by their high sensitivity and by their ability to follow changes many times more rapid than can be followed by previous recording instruments.

41-160–ACO—160,000 Kw at Venice No. 2 Plant of Union Electric Company of Illinois; *R. R. Wisner (A'23) and Stanley Stokes (F'29). 30 cents by mail.* This paper presents the fundamental requirements to be met in providing additional power supply for the St. Louis area. In order to meet these requirements the Venice site is being developed with an initial installation of 160,000 kw and a planned ultimate capacity of about 400,000 kw. The installed capacity consists of two 40,000 kw and one double-winding 80,000 kw, 13.8-kv generator. Steam is provided at 850 pounds per square inch and 900 degrees Fahrenheit by two 360,000-pound-per-hour and two 375,000-pound-per-hour boilers. The bus arrangement is such as to provide direct connection from generators to feeders and through the use of transfer and synchronizing busses to provide for the supply of power to the transmission system or from the transmission system to the feeders. Bus sectionalizing and reactors limit the short circuit duty to less than 2,500,000 kva on the synchronizing bus-sectionalizing breakers and less than 1,500,000 kva on all other breakers. Bus-differential protection is provided. All station auxiliaries are electrically driven.

Power Transmission and Distribution

41-153—Symmetrical Nomenclature of Three-Phase Circuits; *Bryce Brady (M'37). 15 cents by mail.* Two methods of identifying three-phase conductors, voltages, and currents are in general use today. One method, which is called "standard" nomenclature because of its extensive use on power transmission and distribution systems, is based on the 30 degree relation between delta and wye voltage. The other method, which is frequently used for analytical purposes and is called "symmetrical" nomenclature, is based on the 90 degree voltage relation. Shortcomings of the standard scheme and five advantages of the symmetrical plan are discussed.

Protective Devices

41-151-ACO—Design Features of a New High-Capacity Network Protector; *J. W. Seaman (A'32) and R. W. Smith (A'40). 15 cents by mail.* The investigation of ways and means to produce a new high-capacity network protector, suitable for the interrupting and carrying of currents greater than those heretofore encountered in the network field, has resulted in the introduction of a device containing new and interesting features. Chief of these is the use of a new multiple-point contact construction which has distinct advantages over contacts formerly used, from a current-carrying, current-transferring, current-interrupting, and contact-pressure standpoint. The methods employed to obtain data are described. The relationship between various numbers of point contacts in multiple and the consequent change in current limitations are shown. The data obtained provide a basis for the design of contacts suitable for coping with any specified transient current.

41-152—A Novel Reclosing Relay; *P. O. Bobo (M'41). 15 cents by mail.* A reclosing relay, consisting of an assembly of telephone-type relays and designed with features that are not obtainable with standard reclosing relays now available, is used by the Oklahoma Gas and Electric Company to meet the additional reclosing requirements brought about by complete automatization of high-voltage oil circuit breakers in transmission networks and on lines containing automatic sectionalizing airbreak switches. The most important requirements for reclosing relays in such applications are the ability to distinguish between energized and de-energized line conditions, to be fast and accurate in timing between reclosures, and to reset quickly after successful reclosures. It is through the fulfillment of the additional requirements that the relay permits a transmission system to render maximum continuity of service.

Standards • • •

Proposals Offered for the Rating of Electrical Apparatus

As a preliminary step in the current development of a proposed AIEE Standard covering the principles of reading electrical apparatus for short-time, intermittent, or varying duty, the subject is scheduled to be discussed in a technical session and conference at the forthcoming South West District meeting in St. Louis, Mo., October 8–10, 1941. The following is a digest of the Report (AIEE No. 1A) on this topic prepared by the AIEE standards coordinating committee No. 4.

There are two distinct limitations on the available output of electrical apparatus. One is the peak-load ability, as fixed by the breakdown torque, commutation limit, reactance, or fall-in voltage or speed. The other is the thermal limit, as fixed by the heat-storage capacity, the ventilating system, the temperature rise permissible for the type of insulation used, and the desired life expectancy. It is desirable that both of these limits should be indicated in the rating of electrical apparatus for short time, intermittent, or varying duty service.

This report compares the several methods of rating and testing that are now in use and outlines the field for each. It also makes specific recommendations, confirming and extending practices that have been gradually coming into use during recent years. One of these is the use of higher temperature limits for short-time rated than for continuous rated machines. Recognizing the empirical rule that the useful life of organic insulating materials is approximately halved for each 8- to 12-degree centigrade increase in temperature, and that short-time rated apparatus is in operation for only a fraction of the total elapsed time, a limiting temperature rise of 70 degrees centigrade is suggested for 30-minute rated apparatus with Class A insulation; in place of the 50-degree centigrade (by thermometer) value normal for continuous-rated apparatus. Similar increases are suggested for other cases, but the application of these new limits is strictly confined to moderate-sized or small apparatus in which thermal expansion stresses are unimportant, and for short-time service.

The other specific recommendation in the report is the use of the service-factor method of rating, that is especially adapted for intermittent-duty apparatus, such as welding generators. In this method, the nameplate rating indicates the normal or permissible output during periods of sustained high loading, and the rms equivalent over a varying duty cycle, or permissible continuous rating, is indicated by a service factor less than unity applied to the nameplate rating. Under this plan, the only temperature test necessary is a continuous run at the service-factor rating, for which the limiting temperature is normally the same as for continuous-rated apparatus with the same class of insulation.

The report should be read in conjunction with AIEE Standard No. 1, issued in June 1940, which deals with the principles on which temperature limits are based for continuous-rated apparatus.

It is expected that printed copies of this report will be available for distribution prior to the St. Louis meeting. Persons interested should write directly to H. E. Farrer, secretary, AIEE standards committee, 33 West 39th Street, New York, N.Y.

Dielectric Tests Proposed for Outdoor Circuit Interrupters

As a part of the general subject of dielectric tests for electrical equipment currently receiving the active attention of the electrical industry, the AIEE committee on protective devices has recommended to the AIEE standards committee and to other standardizing bodies the use of the values shown in the table as a basis for dielectric tests on outdoor power circuit breakers. At the committee's request these values are submitted here for use and criticism as a preliminary step in the development of a permanent standard.

The impulse values given in the accompanying tabulation are the same as those recommended for outdoor bushings by the AIEE joint committee. The tabulated values now are being considered by other groups of the committee on protective devices for application to other types of apparatus. Wet tests on completed outdoor circuit breakers were omitted because of the complications in making such tests and because the wet tests made on the bushings themselves reasonably serve in lieu of an over-all wet test. The wet tests, however, will be continued on outdoor circuit breaker bushings in line with the recommendation of the joint committee on bushing standardization.

Test Values for Outdoor Power Circuit Breakers of 25,000 Kilovolt-Amperes and Above

Breaker Rating (Kv)	Low-Frequency One-Minute Withstand Test (Kv)	Impulse Test Withstand (Kv)
1.2		
2.5	15	45
5.0	19	60
7.5	26	75
15.0	50	110
23.0	60	150
34.5	80	200
46.0	105	250
69.0	158	350
92.0	209	450
115.0	261	550
138.0	313	650
161.0	365	750
196/230.0	425	900
230.0	485	1,050
287.5	590	1,300
345.0	690	1,550

The AIEE committee on protective devices also has approved the tabulated values for use in AIEE Standard No. 22, "Air Switches and Bus Supports," subject to the qualification that the 23-, 34.5-, and 46-kilovolt classes of this apparatus would not have to meet the new test values until July 1, 1943, because the insulators in these classes do not have to meet the basic insulation levels until January 1, 1943.

Likewise, the tabulated values were adopted for AIEE Standard No. 25, "Fuses—600 Volts and Above," for outdoor fuses rated at 23 kilovolts and up, with the provision that the 23-, 34.5-, and 46-kilovolt air switches would not have to meet the new test values until July 1, 1943. With reference to this apparatus, the committee approved for the 10-second wet test a qualification requiring that completed outdoor fuses of 23 kilovolts and above should withstand twice rated voltage plus one kilovolt.

Personal • • •

Vannevar Bush (A'15, F'24) president, Carnegie Institution of Washington, Washington, D. C., has been named director of the newly-created Office of Scientific Research and Development of the Office of Emergency Management, Washington, D. C. Doctor Bush was born March 11, 1890, in Everett, Mass., and received the degrees of bachelor of science and master of science in electrical engineering from Tufts College in 1913, and doctor of engineering from Massachusetts Institute of Technology and Harvard University in 1916. In 1913 he entered the test department of the General Electric Company, and in 1914

served in the inspection department of the United States Navy. During 1914–15 he was an instructor in mathematics at Tufts College, Medford, Mass., and after doing graduate study at MIT he became assistant professor of electrical engineering at Tufts College. During 1917–18 he was engaged in research on submarine detection in connection with the United States Navy special board on submarine devices. From 1917 to 1922 he was consulting engineer for American Radio and Research Corporation, and was also associate professor of electric power transmission in the department of electrical engineering, Massachusetts Institute of Technology, Cambridge, Mass., from 1919 to 1923 when he was made professor of electric power transmission. He was made vice-president and dean of the MIT school of engineering in 1932, and became president of the Carnegie Institution of Washington in 1938. He is a past director of the AIEE, and was awarded the AIEE Lamme Medal in 1935. He has been active on many Institute committees, and is also a member of the American Academy of Arts and Sciences, the American Physical Society, the Society for the Promotion of Engineering Education, and the National Academy of Sciences. He is the author of "Operational Circuit Analysis", and joint author of "Principles of Electrical Engineering", and author of many technical articles.

Frank Gill (A'03, F'13) vice-president, International Standard Electric Corporation, London, England, was selected from the telephone industry to be knighted in the King's Birthday awards, June 12, 1941, for his part in the development of the telephone industry and international telephony. He was born October 4, 1866, at Castletown, Isle of Man, and from 1882 to 1890 was affiliated with the United Telephone Company, London, and the Telephone Company of Ireland, Dublin. In 1890 he became chief electrician for the Liverpool district of the National Telephone Company, Ltd., and in 1893 was made manager for the Dublin and South of Ireland districts of the company. He became superintendent for Ireland for the company in 1896, and in 1902 was made engineer-in-chief for the whole company. About 1919 he joined the Western Electric Company, London, as European chief engineer, and about 1922 was appointed to the same position with the International Western Electric Company, London. Around 1925 he became European chief engineer for the International Standard Electric Corporation Inc., London, and about 1927 was made vice-president of the company in addition. He was transferred to the office of vice-president of the International Telephone and Telegraph Corporation, Inc., London, the following year, and became vice-president and director of the International Standard Electric Corporation about 1936. He is a past president of the Institution of Electrical Engineers.

R. H. Barclay (A'14, F'28) since 1936 regional director of the Federal Power Commission, New York, N. Y., has resigned this position with the closing of all regional offices of the Commission and concentration of FPC operations in Washington, D. C. From 1908 to 1911 Mr. Barclay was with the Bell Telephone Company of Missouri, St. Louis, Mo., and the Missouri and Kansas Telephone Company, Kansas City, Mo., as chief draftsman, telephone engineer, and superintendent of buildings and power plants for these companies. In 1912 he became assistant electrical engineer for the Kansas City Terminal Railway Company, Kansas City, Mo., and in 1915 joined the Brooklyn-Manhattan Transit Corporation, Brooklyn, N. Y., as assistant engineer. In 1917 he became chief electrical engineer for The Foundation Company, New York, N. Y. He joined Starrett and Van Vleck, Architects, New York, N. Y., as chief electrical engineer, in 1922, and in 1924 became electrical engineer for the Stone and Webster Engineering Corporation, Boston, Mass. From 1913 to 1934 he was president of the manufacturing establishment McClelland Barclay Art Products, Inc., and in 1934 became affiliated with the Federal Power Commission, Washington, D. C., as Chief of the analysis and reports division of the National Power Survey.

J. V. B. Duer (A'15, F'29) chief electrical engineer, Pennsylvania Railroad Company, Philadelphia, Pa., has been appointed assistant to the vice-president of operation for the company. Mr. Duer was born in Poultney, Vt., April 9, 1882, and received the degree of mechanical engineer from Stevens Institute of Technology in 1903. In 1903 he joined the General Electric Company, Lynn, Mass., as electrical apprentice, and in 1904 was transferred to the Schenectady, N. Y., branch of the company. In 1906 he became affiliated with the Long Island Railroad, and served successively as wireman, electrical inspector, and chief clerk to the trainmaster of electrified lines, until 1910 when he became foreman of motormen for the Pennsylvania Railroad, New York, N. Y. In 1913 he was made assistant engineer in charge of electrical department mechanical engineers, for the Pennsylvania Railroad lines east of Pittsburgh and Erie. He became engineer of this department in 1919, and was made electrical engineer for the entire company in 1920. He was promoted to chief electrical engineer in 1935.

L. W. Abbott (A'11, M'21) general manager of installation, Western Electric Company, New York, N. Y., retired in June 1941. He had been with the Bell System since 1900. He became installation engineer for the New England Telephone and Telegraph Company, Boston, Mass., in 1900. In 1902 he was transferred to the engineering department, and in 1912 was appointed supervisor of equipment and building for the company. After serving with the American Expeditionary Forces as captain and major from 1917 to 1919, he returned to his former position with the New England Telephone and Telegraph Company, and was made division superintendent of plant for the company in 1922. In 1923 he became superintendent of installation for the Western Electric Company, New York, N. Y., later serving in the same capacity for the Chicago branch of the company for a short time. He had been general manager of installation for the company since 1935.

T. F. Peterson (A'25, M'32) director, electrical cable works, American Steel and Wire Company, Worcester, Mass., has been appointed director of electric cable engineering and research of the American Steel and Wire Company at the company's headquarters in Cleveland, O. Mr. Peterson was born December 12, 1902, in Brooklyn, N. Y., and received the degrees of bachelor of science, Cooper Union Institute of Technology, 1923, and electrical engineer, Leland Stanford University, 1924. From 1924 to 1925 he was in charge of cable research for the Brooklyn Edison Co., Brooklyn, N. Y., and from 1925 to 1927 was cable engineer for that company. In 1927 he joined the American Steel and Wire Company, New York, N. Y., as cable engineer, later becoming electrical engineer, and in 1931 was transferred to the Worcester, Mass., works of the company as consulting cable engineer. He was appointed director of the electrical cable works at Worcester in 1937.

L. A. Morphey (A'26) formerly superintendent of stations, Northwestern Electric Company, Portland, Ore., has joined the Pacific Power and Light Company, Kennewick, Wash., as assistant superintendent of power. **J. A. Hooper** (A'21) formerly assistant superintendent of stations, will succeed Mr. Morphey as superintendent. Mr. Morphey received the degree of bachelor of science from Montana State College, and became affiliated with the Northwestern Electric Company in 1922. He was made assistant superintendent of stations for the company about 1927, and superintendent of stations about 1930. Mr. Hooper graduated in electrical engineering from Oregon Agricultural College, and was an instructor in the electrical engineering laboratory there from 1917 to 1920. In 1920 he joined the Northwestern Electric Company, as test man. He has been assistant superintendent of stations since about 1936.

H. A. Maxfield (A'21) formerly assistant professor of electrical engineering, Worcester Polytechnic Institute, Worcester, Mass., has been made professor of electrical engineering there. Professor Maxfield was born September 24, 1893, in Lowell, Mass., and received the degree of bachelor of science in electrical engineering from Worcester Polytechnic Institute. From 1916 to 1917 he was employed in the research department of the Westinghouse Electric and Manufacturing Company, at East Pittsburgh, Pa., and for the company at Worcester Polytechnic Institute. From 1917 to 1920 he served as a captain in the heavy artillery of the United States Army, and in 1920 returned to Westinghouse as research engineer. The following year he went to Worcester Polytechnic Institute to do research work in the electrical engineering laboratory there, and in 1922 was made instructor in electrical engineering. He has been assistant professor since about 1927.

S. M. Sharp (A'26) formerly electrical engineer for the Shreveport, La., division of the Southwestern Gas and Electric Company, has been made chief engineer for the company. Born October 14, 1901, in Alma, Ark., Mr. Sharp received the degree of

bachelor of electrical engineering from the University of Arkansas in 1924. After a year in the graduate student test course of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., he became assistant engineer for the East St. Louis and Suburban Railway Company, East St. Louis, Ill., in 1924. He joined the Minnesota Power and Light Company, Duluth, Minn., in 1926, as assistant engineer, and about 1927 became electrical engineer for the Central and Southwest Utilities Company, Dallas, Tex. He has been electrical engineer for the Southwestern Gas and Electric Company since about 1932.

D. M. Simmons (A'22, F'28) vice-president, General Cable Corporation, New York, N. Y., has been appointed a member of a liaison committee set up by the Office of Production Management as a co-ordinating link between the electrical industry and the government defense activities. Also serving on the committee are: **C. L. Collens** (A'07, M'40) president, Reliance Electric and Engineering Company, Cleveland, Ohio; **R. W. McChesney** (A'20, M'28) executive vice-president, Harry Alexander, Inc., Washington, D. C., representing National Electrical Contractors Association; **J. W. McNair** (A'25) electrical engineer, American Standards Association, New York, N. Y.; **J. M. Newton** (A'18, F'37) president, Oakes Electric Supply Company, Holyoke, Mass.; and **E. O. Shreve** (A'06) vice-president, General Electric Company, Schenectady, N. Y.

G. R. Benjamin (A'07) has recently retired as engineer of automatics for the Western Union Telegraph Company, New York, N. Y. He had been with the company for 52 years. Mr. Benjamin was born November 25, 1873, in Hartford, Conn. He entered the service of Western Union, New York, in 1888, working as messenger, operator, chief operator, and electrician, at various times. In 1903 he was transferred to the engineering department, to do developmental work, and became automatics engineer in 1912. He was instrumental in developing the Barclay Printing Telegraph System, the Western Union Multiplex System, and numerous other inventions in the field of telegraphic operation and transmission.

W. A. Dudley (M'27) assistant engineer of automatics, engineering department, Western Union Telegraph Company, New York, N. Y., has been appointed engineer of automatics, to succeed G. R. Benjamin, retired. Mr. Dudley was born November 28, 1895, at Colebrook, N. H., and received the degrees of bachelor of science in electrical engineering, 1917, and electrical engineer, 1925, from the University of New Hampshire. He has been with the Western Union Telegraph Company in Boston, Mass., and New York, N. Y., since 1917, except for a period during the first world war when he served as a second lieutenant in the United States Air Service. He was made assistant engineer of automatics in 1920.

C. R. Horrell (A'16, M'25) general sales manager, Sangamo Electric Company, Springfield, Ill., has been elected vice-president and general sales manager of the company. Mr. Horrell was born December 15, 1889, in Stockville, Nebr., and received the degree of bachelor of science in electrical engineering from the University of Illinois in 1913. In 1913 he joined the engineering staff of the engineering sales department of the Electric Appliance Company, Chicago, Ill., and from 1916 to 1918 acted as meter specialist for the company. He became assistant sales manager of the Sangamo Electric Company in 1918, and was made general sales manager in 1922.

Dean Harvey (A'04, M'13) materials engineer of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been elected vice-president of the American Society for Testing Materials. Mr. Harvey was born January 2, 1879, in Chicago, Ill., and received the degree of electrical engineer from Armour Institute of Technology in 1905. From 1900 to 1904 he was an engineer in the electrical department of the Underwriters' Laboratories, Chicago, Ill., taking charge of the department in 1902. In 1904 he became electrical engineer for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and in 1911 was made materials engineer.

A. D. Hinckley (A'27, M'38) assistant to the dean, Columbia University School of Engineering, New York, N. Y., has been elected general secretary of the Illuminating Engineering Society for 1941–42. **O. P. Cleaver** (A'36) head of the illumination section of the commercial engineering department, Westinghouse Lamp Division, Westinghouse Electric and Manufacturing Company, Bloomfield, N. J., has been elected regional vice-president for the northeastern region of the society. **F. A. Hansen** (M'31) managing director, the Western Institute of Light and Vision, Los Angeles, Calif., has been elected regional vice-president for the Pacific Coast region.

C. F. Bowman (A'24, M'30) formerly chief engineer, Montana Railroad and Public Service Commission, Helena, Mont., has become senior assistant utilities engineer with the Maryland Railroad and Public Utility Commission. Mr. Bowman was an instructor in electrical engineering at Purdue University, Lafayette, Ind., from 1923 to 1929, and in 1929 became assistant professor of electrical engineering at Montana State College, Bozeman, Mont. He had been chief engineer for the Montana Railroad and Public Service Commission since 1939. He was chairman of the AIEE Montana Section from 1939 to 1941.

F. W. Brockhoff (A'38) formerly general foreman of the substation division, Union Electric Company of Missouri, St. Louis, Mo., has been appointed to the newly-created position of safety engineer for the company.

E. C. Stone (M'19, F'31) vice-president and general manager of the Duquesne Light Company, Pittsburgh, Pa., has been appointed chairman of the Pittsburgh Defense Council to work under the National Civilian Defense Council.

R. D. Yoder (A'40) sales department, Cutler-Hammer, Inc., Milwaukee, Wis., has been transferred from the Milwaukee headquarters of the company to the Cincinnati office.

K. T. Compton (F'31) president of the Massachusetts Institute of Technology, Cambridge, Mass., has been elected to membership on the advisory council of the National Broadcasting Company.

J. H. Foote (A'18, F'32) supervising engineer, Commonwealth and Southern Corporation, Jackson, Mich., has been elected director-at-large of the Michigan Engineering Society for 1941–42.

Obituary • • •

Bancroft Gherardi (A'95, M'04, F'12) retired vice-president and chief engineer of the American Telephone and Telegraph Company, New York, N. Y., and a past president of the Institute, died August 14, 1941. Doctor Gherardi was born April 6, 1873, in San Francisco, Calif., and received the degrees of bachelor of science, 1891, from the Polytechnic Institute of Brooklyn, mechanical engineer, 1893, and master of mechanical engineering, 1894, from Cornell University, and honorary degrees of doctor of engineering from the Polytechnic Institute of Brooklyn, 1933, and from Worcester Polytechnic Institute, 1936. In 1895 he joined the Metropolitan Telephone and Telegraph Company (later the New York Telephone and Telegraph Company) New York, N. Y., as an assistant engineer, and from 1900 to 1901 was engineer of the traffic department of the company. He was transferred to the position of chief engineer for the New York and New Jersey Telephone Company in 1901, and in 1906 returned to New York as assistant chief engineer for the New York Telephone and Telegraph Company and the New Jersey Telephone Company. In 1907 he was made engineer of plant of the American Telephone and Telegraph Company, New York, N. Y. He became acting chief engineer in 1918, and was appointed chief engineer in 1919. In 1920 he was made vice-president and chief engineer for the company, a position which he held until his retirement in 1938. Doctor Gherardi had been active in the affairs of the Institute, having served as a manager, 1905–08 and 1914–17; vice-president, 1908–10; and president, 1927–28; as a member of several committees and chairman of the committee on Institute policy from 1930 to 1933. He had served as a member of the board of directors of the American Standards Association, United Engineering Societies, and United Engineering Societies Library Board; and had represented the Institute on the National Research Council, United States National Committee of the International Electrotechnical Commission, John Fritz Medal board of award, and the Charles A. Coffin Fellowship and Research Fund Committee. Doctor Gherardi received the Edison Medal in 1932. In 1923 the Japanese Government conferred on him the emblem of the Fourth Order of the Rising Sun. He was also a member of the National Academy of Sciences and the Franklin Institute. He had contributed many articles to technical publications.

Edward Jones Willis (A'97, M'00, F'13) consulting engineer, Richmond, Va., died July 11, 1941. Mr. Willis was born April 1, 1866, in Savannah, Ga., and graduated in mechanical engineering from Stevens Institute in 1888. From 1889 to 1890 he was assistant chemist in the Virginia State Agricultural Department, Richmond, Va., and in 1892 he became an engineer for the Richmond Mica Company. In 1893 he became a draftsman for the Talbot Machine Works, and in 1894 was made general manager of the company. In 1896 he joined the Richmond Traction Company as engineer, becoming superintendent of operation in 1897. From 1898 to 1900 he was steam and electrical engineer for the James River Construction Company, Richmond, Va., and in 1900 became president of the Richmond Electric Works. From 1900 to 1915 he was proprietor of the works, and subsequently went into private practice. During 1917–19 he was associated with the United States Fuel Administration, serving as administrative engineer and director of conservation in Virginia, and from 1919 to 1921 he was chairman of the governor's board of mechanical survey. He was the owner of several patents in the fields of astronomy and navigation, and was the author of "The Methods of Modern Navigation" and other books and monographs. He was also a member of The American Society of Mechanical Engineers, the American Mathematical Society, and the American Association for the Advancement of Science.

John Martin Schreiber (A'03) general manager in charge of plant, Public Service Transportation Company, Newark, N. J., died July 18, 1941. He was born in Ironton, Ohio, September 16, 1876, and received a degree in electrical engineering from Ohio State University in 1899. He joined the Cleveland Electric and Railway Company, Cleveland, Ohio, in 1899, and was made engineer in charge of drafting rooms in 1901. In 1903 he joined the Public Service Corporation of New Jersey as assistant engineer of street railway operations, and became engineer of new shops and was also put in charge of the drafting room of the mechanical department, in 1904. He subsequently was made engineer of maintenance of way, and in 1917 became chief engineer in charge of maintenance of way. He had been general manager in charge of plant since 1927. Mr. Schreiber had made several trips to traffic centers of England, France, and Germany to study transportation problems and engineering developments in those countries. He was a past president of the American Transit Engineering Association, and had been chairman of the special consulting and development committee of the National Association of Motor Bus Operators since 1933. He was also a member of the American Railway Engineering Association, the Society of Automotive Engineers, and the American Society of Civil Engineers.

Alfred Victor Guillou (M'27) consulting engineer, department of water and power, City of Los Angeles, Calif., died in December 1940 according to information just received at Institute headquarters. Born at Ventura, Calif., July 29, 1889, he graduated in electrical engineering from the University of California in 1912. From 1912 to 1914 he served an apprenticeship in the ship and test departments of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. In 1914 he became sales engineer for the Pacific Light and Power Corporation, Los Angeles, Calif., and in 1916 was made district agent for its successor, the Mt. Whitney Power and Electric Company, Porterville, Calif. In 1919 he was transferred to the engineering department of the Southern California Edison Company, Los Angeles, Calif. (also a successor to the Pacific Light and Power Corporation). He became assistant engineer for the gas and electric division of the California Railroad Commission in 1920, and was appointed gas and electric engineer for the Commission in 1923. He became assistant chief engineer of the Commission in 1926. From 1931 to 1933 he was chief engineer for the Public Service Commission of Wisconsin, and had been engineer for the City of Los Angeles department of water and power since 1933.

Charles Ernest Canfield (A'02, M'34) retired mechanical engineer, the General Electric Company, Pittsfield, Mass., died July 12, 1941. He was born October 13, 1870, at Arlington, Vt., and received the degree of bachelor of science in electrical engineering from the University of Vermont in 1898. From 1888 to 1890 he was assistant to a patent attorney at Bennington, Vt., and from 1890 to 1895 he was employed as mechanical draftsman with the Gilbert Car Manufacturing Company, Troy, N. Y., Brown and Sharpe Company, Providence, R. I., the Lamokin Car Company, Chester, Pa., and William Sellers and Company, Philadelphia, Pa. In 1899 he became assistant engineer of design of a-c generators for the Stanley Electric Company, Pittsfield, Mass., and in 1904 joined the Western Electric Company, Chicago, Ill., as engineer in charge of a-c generator design. He became chief engineer for the Warren Electric Company, Sandusky, Ohio, in 1908, and in 1909 went to Petersborough, Ont., Canada, as engineer in charge of a-c generator design for the Canadian General Electric Company. He joined the General Electric Company, Pittsfield, Mass., as mechanical engineer, in 1919. He retired from this position in 1941.

Henry T. Purdy (A'13, M'27) president, H. T. Purdy, Inc., San Jose, Costa Rica, Central America, died January 31, 1940. Mr. Purdy was born in Brooklyn, N. Y., February 22, 1866. From 1879 to 1895 he served as apprentice machinist, journeyman machinist, and construction engineer for various electric companies. In 1895 he became superintendent and engineer for the Georgetown and Tenallytown Railway, and Potomac Light and Power Company, Washington, D. C., and in 1898 became construction engineer for the Costa Rica Electric Light and Traction Company, San Jose, Costa Rica. He later was made manager for the company. In 1905 he became staff engineer for the Abangarez Gold Fields and Boston and Central America Mines and Development Company, Costa Rica, later becoming assistant to the manager and then acting manager for Costa Rica. In 1908 he formed the Purdy Engineering Company (later H. T. Purdy, Inc.), engaging in consulting, constructing, and contracting business and representing American machinery manufacturers in Central America. He served as president of the company until the time of his death.

Friedrick Eichberg (F'28) consulting research engineer for the Stinson division of the Vultee Aircraft Corporation's Wayne, Mich., plant, died July 30, 1941. Born in Vienna, Austria, September 10, 1875, Doctor Eichberg graduated from the Technische Hochschule Wien, and was an assistant professor there from 1896 to 1899. In 1899 he became affiliated with the A.E.G.-Union Electric and Manufacturing Company of Austria and Germany, as consulting engineer and manager of the railway department. He was made manager of the company in 1921 and a member of the board of directors of the A.E.G., Berlin, in 1926. At the same time he was general manager of the Linke-Hoffman car and locomotive factory at Breslau, Germany. He came to America in 1938. He was the owner of several patents, among them one for the Winter-Eichberg single-phase railway motor. He was the recipient of a special doctorate from the Technische Hochschule in Breslau, and was a former director of the Bavarian Technological Museum at Munich.

LeRoy Ormand Ripley (A'05) retired president of the Kansas Gas and Electric Company, Wichita, Kansas, died July 22, 1941. Born April 20, 1877, at Laurens, N. Y., he graduated in electrical engineering from Union College in 1900. After working for a short time on electrical installation and construction in Cooperstown, N. Y., he took charge of construction of a municipal power plant in Marathon, N. Y., in 1902, and was also in charge of operation of the plant for a short time He became superintendent of the light and power department of the Schenectady Railway Company, Schenectady, N. Y., in 1903, and in 1905 when the illuminating functions of the company were made a separate branch he was made manager of the Schenectady Illuminating Company. In 1909 he became vice-president of the newly-organized Kansas Gas and Electric Company, and was made president about 1931. He retired as president of the company in June 1940, but continued to serve in a consulting capacity. He received an honorary degree from Union College in 1940.

John P. Otis (A'27) chief of mechanical section, construction division, United States Indian Service, Washington, D. C., died February 17, 1941. Born January 3, 1904, in Baltimore, Maryland, Mr. Otis received the degree of bachelor of engineering in electrical engineering from Johns Hopkins University. From 1922 to 1924 he was with the General Electric Company, Baltimore, Md., as tester and later as switchboard assembler. After a short time as tester for the Locke Insulator Corporation, Baltimore, he again joined the General Electric

Company, Baltimore, in 1925, as a designer. About 1927 he became an instructor in the Boys' Vocational School, Baltimore, and the following year he became associated with the firm of Lowekamp and Otis, as electrical contractor. About 1930 he was made assistant electrical engineer in the bureau of yards and docks, Navy Department, Washington, D. C., and later transferred to the Bureau of Indian Affairs, Department of the Interior, Washington, D. C., as superintendent of construction. He was made chief of the mechanical section about 1939.

Frederick W. Hehre (A'13, M'15, F'29) head of the department of electrical engineering, Columbia University, New York, N. Y., died July 27, 1941. Born November 1, 1886, in New York, N. Y., Professor Hehre received the degree of electrical engineer from Columbia University in 1908. After a year as an inspector for the New York Edison Company, New York, N. Y., he became an instructor in electrical engineering at Columbia University in 1909. He was made assistant professor of electrical engineering in 1916. From 1917 to 1919 he was a lieutenant in the United States Naval Reserve Force, serving as electrical officer and engineer officer. He returned to Columbia University and in 1924 was made associate professor of electrical engineering. He became full professor in 1938, and shortly before his death had been appointed to head the department of electrical engineering. He was co-author of "Electrical Circuits and Machinery" and author of technical articles.

Robert Elmore Lyle (A'32) assistant electrical engineer, system engineering section, engineering division, Bonneville Power Administration, Portland, Ore., died July 20, 1941. Born July 1, 1908, at Pullman, Wash., Mr. Lyle received the degree of bachelor of science in electrical engineering from Washington State College in 1930. He enrolled in the graduate student course of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1930, and later did graduate study at the University of Pittsburgh. In 1935 he became electrical engineer for the Washington State College engineering experiment station, Pullman, Wash., and in 1937 joined the Westinghouse Electric and Manufacturing Company, Seattle, Wash., as engineer. The following year he became electrical engineer for the City of Tacoma department of utilities, Tacoma, Wash., and in 1939 was employed as a junior engineer on the Bonneville Project, Portland, Ore., later becoming assistant electrical engineer.

Edward A. Harley (A'06) retired, formerly supervisor of d-c substations, New York Edison Company, New York, N. Y., died July 9, 1941. He was born July 27, 1870, in Brooklyn, N. Y., and in 1884 joined the Edison Electric Illuminating Company of New York, later New York Edison, one of the predecessors of the Consolidated Edison Company of New York, Inc. After working for some time in the meter, operating, testing, and installation departments, he was made assistant operating superintendent of the first district for the company in 1895. He became assistant operating superintendent of the third district in 1901, and from 1902 to about 1930 was operating superintendent in charge of the third district. He then became supervisor of the bureau of substations for the company, and later supervisor of d-c substations, retiring from that position about 1935.

James Carr Smith (A'20) commercial manager, Charleston division, Appalachian Electric Power Company, Charleston, W. Va., died July 18, 1941. Mr. Smith was born November 29, 1871, at Chilhowie, Smythe County, Va., and received the degree of bachelor of science from Milligan College in 1900. After some time as chief clerk, paymaster, and superintendent of mines and quarries for the Virginia Iron Coal and Coke Company, Bristol, Radford, and Roanoke, Va., he became assistant to the vice-president and general manager of the Virginian Power Company, Charleston, W. Va., in 1914. When the Virginian Power Company was merged with the Appalachian Electric Power Company about 1918, he was made commercial manager and purchasing agent for the Charleston division of the latter. He was also a member of the National Electric Light Association.

Newell M. Porter (A'31) maintenance engineer, Southwestern Bell Telephone Company, Oklahoma City, Oklahoma, died May 29, 1941. Mr. Porter was born February 14, 1895, in Crockett, Texas. From 1914 to 1917 he worked as a repairman, and in 1917 joined the Western Electric Company as installer and tester in the installation department. He was made job foreman for the company in 1924, in charge of supervision of the installation of central office telephone equipment. He became equipment engineer for the Southwestern Bell Telephone Company, in 1929, and later in that year was made maintenance engineer for the company at Oklahoma City.

John Corliss Bennett (A'90, M'13) retired, formerly commercial engineer with the General Electric Company, New York, N. Y., died August 2, 1941. He was 75 years of age. Mr. Bennett joined the General Electric Company in 1898, after 8 years spent in designing various small central stations. From 1898 to 1909 he was in charge of the estimating department at the New York office of the company, and in 1909 he became commercial engineer, a position which he held until his retirement 11 years ago.

Wilfred Joseph Lacerte (A'28) telephone systems development engineer, Bell Telephone Laboratories, Inc., New York, N. Y., died October 12, 1940. Mr. Lacerte was born January 20, 1899 in Granby, Canada, and received the degree of bachelor of science in electrical engineering from the University of Kansas in 1923. He joined the Bell Telephone Laboratories in 1923 as telephone systems development engineer, a position which he held until the time of his death.

Membership • •

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before September 30, 1941, or November 30, 1941 if the applicant resides outside of the United States or Canada.

United States and Canada

1. NORTH EASTERN

Casler, C. L., Central New York Power Corporation, Syracuse, N. Y.
Marriott, E. E., Lone Star Cement Corporation, Hudson, N. Y.
Molloy, J. J., Cambridge Electric Light Company, Cambridge, Mass.
Port, R. F. (Associate re-election), Central New York Power Corporation, Syracuse, N. Y.
Rhea, T. R., General Electric Company, Schenectady, N. Y.

2. MIDDLE EASTERN

Feder, J. B. (Member re-election), Department of Commerce, Washington, D. C.
Kamoroff, D., United States War Department, Aberdeen Proving Grounds, Md.
Miller, C. F., Johns Hopkins University, Baltimore, Md.

3. NEW YORK CITY

Beger, A. R. (Associate re-election), Ward Leonard Electric Company, Mount Vernon, N. Y.
Boughtwood, J. E., Western Union Telegraph Company, New York, N. Y.
Miller, H. G., J. G. White Engineering Corporation, New York, N. Y.
Reynolds, H. B. (Member), New York City Transit System, New York, N. Y.
Smith, R. D. (Member), Merck and Company, Incorporated, Rahway, N. J.

4. SOUTHERN

Banning, F. D. (Member), Florida Power and Light Company, Miami.
Edmonds, J. R., Freeport Sulphur Company, Port Sulphur, La.
Ely, R. B., U. S. Engineer Office, Charleston, S. C.

5. GREAT LAKES

Hubbard, E. L., General Electric Company, Detroit, Mich.
Ikerd, H. M., Iowa State College, Ames.
Koetsier, A. J., Westinghouse Electric and Manufacturing Company, Detroit, Mich.
Lorimer, J. L., David Bradley Manufacturing Company, Bradley, Ill.
Messer, G. E., General Electric Company, Detroit, Mich.
Ogden, W. F. (Member), Edison General Electric Appliance Company, Inc., Chicago, Ill.

7. SOUTH WEST

Gower, S. G., United States Government, Duncan Field, South San Antonio, Tex.
Parker, T. R., 200th Coast Artillery (AA) AATC, Fort Bliss, Tex.

8. PACIFIC

Chambers, W. W., Navy Department, Bureau of Ordnance, Long Beach, Calif.
Davis, J. H. (Member), Department of Water and Power, Los Angeles, Calif.
Hart, L., Associated Telephone Company, Ltd., Santa Monica, Calif.
Keene, K. W., 115 San Rafael Avenue, San Rafael, Calif.
Purdon, A. (Associate re-election), Crocker-Wheeler Electric Manufacturing Company, San Francisco, Calif.
White, G. A., United States Army, Quartermaster Corps, Fort Huachuca, Ariz.
Wood, L. M., Douglas Aircraft Company, Santa Monica, Calif.

9. NORTH WEST

Jervis, J. R., Westinghouse Electric and Manufacturing Company, Seattle, Wash.
Palo, G. M. (Member), Siems Drake Puget Sound, Seattle, Wash.

10. CANADA

Laverock, D. J., Columbia Power Company, Limited, Vancouver, B. C.
Mable, W. H., H. G. Acres and Company, Niagara Falls, Ont.

Total, United States and Canada, 35

Elsewhere

Hatfield, S. A., Royal Air Force Station, Kabrit, Egypt.
Kumar, C. R., The Indian Scientific Services Registered, Tuni, India.

Total, elsewhere, 2

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District	Chairman (Vice-President, AIEE)	Secretary (District Secretary)	Chairman, District Committee on Student Activities
1 North Eastern	Everett S. Lee, General Electric Co., Schenectady, N. Y.	R. G. Lorraine, General Electric Co., Schenectady, N. Y.	E. A. Walker, Tufts College, Medford, Mass.
2 Middle Eastern	N. S. Hibshman, Lehigh University, Bethlehem, Pa.	J. E. Treweek, Pennsylvania Power and Light Company, 117 E. Broad St., Hazleton, Pa.	H. S. Buecheler, Villanova College, Villanova, Pa.
3 New York City	J. W. Barker, Columbia University, New York, N. Y.	George Sutherland, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York, N. Y.	D. H. Wright, Pratt Institute, Brooklyn, N. Y.
4 Southern	J. Elmer Housley, Aluminum Co. of America, Alcoa, Tenn.	A. S. Hoefflin, Louisville Gas and Electric Co., 311 W. Chestnut St., Louisville, Ky.	C. B. Norris, Tulane University, New Orleans, La.
5 Great Lakes	K. L. Hansen, 2916 N. Prospect Ave., Milwaukee, Wis.	A. G. Dewars, Northern States Power Co., 15 S. 5th St., Minneapolis, Minn.	E. A. Reid, University of Illinois, Urbana, Ill.
6 North Central	Arthur L. Jones, General Electric Co., P.O. Box 2331, Denver, Colo.	Murray G. Graff, General Electric Co., 650 17th St., Denver, Colo.	F. B. Beatty, Colorado State College, Fort Collins, Colo.
7 South West	J. L. Hamilton, 1806 Pine St., St. Louis, Mo.	L. L. Crump, J. R. Kearney Corp., 4224 Clayton Ave., St. Louis, Mo.	R. S. Glasgow, Washington University, St. Louis, Mo.
8 Pacific	Walter C. Smith, General Electric Co., 823 Russ Bldg., San Francisco, Calif.	E. M. Wright, Pacific Gas and Electric Co., 245 Market St., San Francisco, Calif.	C. F. Daniel, University of California, Berkeley, Calif.
9 North West	A. LeRoy Taylor, University of Utah, Salt Lake City, Utah	A. C. Kelm, Utah Power and Light Co., Salt Lake City, Utah	R. H. Hull, University of Idaho, Moscow, Idaho
10 Canada	C. A. Price, Canadian Westinghouse Co., Ltd., Sanford Ave. N., Hamilton, Ont.	John M. Somerville, Canadian Porcelain Co., Ltd., Box 428, Hamilton, Ont.	

NOTE: Each District executive committee includes also the chairmen and secretaries of all Sections within the District, and the District vice-chairman of the national membership committee.

Institute Representatives (continued)

Marston Medal Board of Award

Bion J. Arnold

National Bureau of Engineering Registration, Advisory Board

W. I. Slichter

National Fire Protection Association, Electrical Committee

F. V. Magalhaes — H. S. Warren, *Alternate*

National Fire Waste Council

Willis Maclachlan — Frank Thornton, Jr.

National Research Council, Division of Engineering and Industrial Research

John C. Parker

Research Procedure Committee, Engineering Foundation

L. W. Chubb

United Engineering Trustees, Inc.

F. M. Farmer — C. E. Stephens

United States National Committee of the International Commission on Illumination

J. W. Barker — Robin Beach — Clayton H. Sharp

United States National Committee of the International Electrotechnical Commission

R. E. Hellmund — V. M. Montsinger — H. S. Osborne

Alternates

H. E. Farrer — E. L. Moreland — B. B. Paxton

Washington Award Commission

H. B. Gear — L. W. W. Morrow

Student Branches of the Institute

Name and Location	District	Counselor (Member of Faculty)
Akron, Univ. of, Akron, Ohio	2	J. T. Walther
Alabama Polytechnic Inst., Auburn	4	W. W. Hill
Alabama, Univ. of, University	4	W. J. Miller
Alberta, Univ. of, Edmonton, Can.	10	R. G. Cullwick
Arizona, Univ. of, Tucson	8	J. C. Clark
Arkansas, Univ. of, Fayetteville	7	W. B. Stelzner
British Columbia, Univ. of, Vancouver, Can.	10	W. B. Coulthard
Brooklyn, Polytechnic Inst. of, Brooklyn, N. Y.	3	A. B. Giordano
Brown Univ., Providence, R. I.	1	F. N. Tompkins
Bucknell Univ., Lewisburg, Pa.	2	J. B. Miller
Calif. Inst. of Tech., Pasadena	8	F. W. Maxstadt
Calif., Univ. of, Berkeley	8	C. F. Dalziel
Carnegie Inst. of Tech., Pittsburgh, Pa.	2	G. R. Patterson
Case School of Applied Science, Cleveland, Ohio	2	P. L. Hoover
Catholic Univ. of America, Washington, D. C.	2	T. J. MacKavanagh
Cincinnati, Univ. of, Cincinnati, Ohio	2	L. R. Culver
Clarkson College of Technology, Potsdam, N. Y.	1	A. R. Powers
Clemson Agricultural College, Clemson, S. C.	4	A. B. Credle
Colorado State Col. of A.&M. Arts, Fort Collins	6	F. B. Beatty
Colorado, Univ. of, Boulder	6	H. B. Palmer
Columbia Univ., New York, N. Y.	3	G. T. Harness
Connecticut, Univ. of, Storrs	1	E. A. Walker
Cooper Union, New York, N. Y.	3	N. L. Towle
Cornell Univ., Ithaca, N. Y.	1	W. W. Cotner
Denver, Univ. of, Denver, Colo.	6	
Detroit, Univ. of, Detroit, Mich.	5	H. O. Warner
Drexel Inst. of Technology, Philadelphia, Pa.	2	E. O. Lange
Duke Univ., Durham, N. C.	4	O. J. Meier, Jr.
Florida, Univ. of, Gainesville	4	E. F. Smith
George Washington Univ., Washington, D. C.	2	A. G. Kunis
Georgia School of Technology, Atlanta	4	H. B. Duling
Harvard Univ., Cambridge, Mass.	1	J. D. Cobine
Idaho, Univ. of, Moscow	9	J. H. Johnson
Illinois Inst. of Technology, Chicago	5	E. H. Freeman
Illinois, Univ. of, Urbana	5	E. A. Reid
Iowa State Col., Ames	5	B. S. Willis
Iowa, Univ. of, Iowa City	5	H. R. Reed
Johns Hopkins Univ., Baltimore, Md.	2	W. B. Kouwenhoven
Kansas State Col., Manhattan	7	R. G. Kloeffler
Kansas, Univ. of, Lawrence	7	R. J. W. Koopman
Kentucky, Univ. of, Lexington	4	B. Barnett
Lafayette Col., Easton, Pa.	2	F. W. Smith
Lehigh Univ., Bethlehem, Pa.	2	J. L. Beaver
Louisiana State Univ., Baton Rouge	4	W. D. Morris
Louisville, Univ. of, Louisville, Ky.	4	J. M. Houchens
Maine, Univ. of, Orono	1	A. S. Hill
Manhattan Col., New York, N. Y.	3	H. J. Lockwood
Marquette Univ., Milwaukee, Wis.	5	E. W. Kane
Maryland, Univ. of, College Park	2	L. J. Hodgins
Mass. Inst. of Technology, Cambridge	1	A. E. Fitzgerald
Michigan Col. of Mining & Tech., Houghton	5	G. W. Swenson
Michigan State Col., East Lansing	5	M. M. Cory
Michigan, Univ. of, Ann Arbor	5	J. S. Gault
Milwaukee School of Engg., Milwaukee, Wis.	5	E. L. Wiedner
Minnesota, Univ. of, Minneapolis	5	J. H. Kuhlmann
Mississippi State Col., State College	4	H. C. Simrall
Missouri School of Mines & Met., Rolla	7	J. Stuart Johnson
Missouri, Univ. of, Columbia	7	D. Waldelich
Montana State Col., Bozeman	9	G. Fiedler
Nebraska, Univ. of, Lincoln	6	L. A. Bingham
Nevada, Univ. of, Reno	8	S. G. Palmer
Newark Col. of Engineering, Newark, N. J.	3	C. H. Stephan
New Hampshire, Univ. of, Durham	1	L. W. Hitchcock
New Mexico State Col., State College	7	Luther Johnson
New Mexico, Univ. of, Albuquerque	7	H. L. Jones
New York, Col. of the City of, New York	3	Harry Baum
New York Univ., New York	3	H. N. Walker
North Carolina State Col., Raleigh	4	L. M. Kreyer
North Dakota State Col., Fargo	6	H. S. Rush
North Dakota, Univ. of, Grand Forks	6	H. F. Rice
Northeastern Univ., Boston, Mass.	1	R. G. Porter
Northwestern Univ., Evanston, Ill.	5	E. W. Kimbark
Norwich Univ., Northfield, Vt.	1	D. E. Howes
Notre Dame, Univ. of, Notre Dame, Ind.	5	J. A. Northcott
Ohio Northern Univ., Ada	2	D. S. Pearson
Ohio State Univ., Columbus	2	S. O. Evans
Ohio Univ., Athens	2	W. M. Young
Oklahoma A.&M. College, Stillwater	7	A. Naeter
Oklahoma, Univ. of, Norman	7	C. L. Farrar
Oregon State Col., Corvallis	9	A. L. Albert
Pennsylvania State Col., State College	2	P. X. Rice
Pennsylvania, Univ. of, Philadelphia	2	S. R. Warren, Jr.
Pittsburgh, Univ. of, Pittsburgh, Pa.	2	R. C. Gorham
Puerto Rico, Univ. of, Mayagues, P. R.	3	G. F. Anton
Pratt Institute, Brooklyn, N. Y.	3	D. H. Wright
Princeton Univ., Princeton, N. J.	2	A. B. Vivell
Purdue Univ., Lafayette, Ind.	5	J. H. Bowman
Rensselaer Polytechnic Inst., Troy, N. Y.	1	L. C. Holmes
Rhode Island State Col., Kingston	1	W. B. Hall
Rice Inst., Houston, Tex.	7	S. H. Van Wambeck
Rose Polytechnic Inst., Terre Haute, Ind.	5	C. C. Knipmeyer
Rutgers Univ., New Brunswick, N. J.	3	F. P. Fischer
Santa Clara, Univ. of, Santa Clara, Calif.	8	E. F. Peterson
South Carolina, Univ. of, Columbia	4	Samuel Litman
South Dakota State College, Brookings	6	W. H. Gamble
South Dakota State School of Mines, Rapid City	6	E. E. Clarke
Southern California, Univ. of, Los Angeles, Calif.	8	J. K. Nunan
Southern Methodist Univ., Dallas, Tex.	7	H. F. Huffman
Stanford Univ., Stanford University, Calif.	8	H. H. Skilling
Stevens Inst. of Technology, Hoboken, N. J.	3	W. L. Sullivan
Swarthmore Col., Swarthmore, Pa.	2	J. D. McCrumm
Syracuse Univ., Syracuse, N. Y.	1	C. W. Henderson
Tennessee, Univ. of, Knoxville	4	W. O. Leffell
Texas A.&M. Col., College Station	7	N. F. Rode
Texas Technological Col., Lubbock	7	W. F. Gray
Texas, Univ. of, Austin	7	R. A. Galbraith
Tufts College, Tufts College, Mass.	1	A. H. Howell
Tulane Univ., New Orleans, La.	4	C. B. Norris
Union Col., Schenectady, N. Y.	1	J. B. Paul
Utah, Univ. of, Salt Lake City	9	P. L. Poole
Vermont, Univ. of, Burlington	1	E. R. McKee
Villanova Col., Villanova, Pa.	2	H. S. Bueche
Virginia Military Inst., Lexington	4	J. S. Jamison
Virginia Polytechnic Inst., Blacksburg	4	Claudius Lee
Virginia Univ. of, University	4	L. R. Quarles
Washington, State College of, Pullman	9	H. F. Lickey
Washington, Univ. of, Seattle	9	R. E. Lindblom
Washington Univ., St. Louis, Mo.	7	H. G. Hake
West Virginia Univ., Morgantown	2	A. H. Forman
Wisconsin, Univ. of, Madison	5	R. R. Benedict
Worcester Polytechnic Inst., Worcester, Mass.	1	V. Siegfried
Wyoming, Univ. of, Laramie	6	G. H. Sechrist
Yale Univ., New Haven, Conn.	1	A. G. Conrad

Total Branches 123

Local Sections of the Institute

Name	District	When Organized	Membership Aug. 1, 1941	Chairman	Secretary	Secretary's Address
Akron	2	Aug. 12, '20	87	C. J. Miller, Jr.	K. F. Sibila	University of Akron, Akron, Ohio
Alabama	4	May 22, '29	45	W. J. Miller	R. E. Williams, Jr.	Westinghouse Electric and Mfg. Co., Birmingham, Ala.
Arizona	8	Mar. 22, '41	28	Ben Ferguson	W. H. Croft	Central Arizona Light and Power Co., Phoenix, Ariz.
Boston	1	Feb. 13, '03	439	J. M. Murray	W. I. Middleton	Simplex Wire and Cable Co., Cambridge, Mass.
Central Indiana	5	Jan. 12, '12	144	L. J. Dunnewold	J. R. Pies	R.C.A. Mfg. Co., Inc., Indianapolis, Ind.
Chicago	5	1893	810	K. Y. Glentzer	J. C. Woods	Commonwealth Edison Co., Chicago, Ill.
Cincinnati	2	June 30, '20	212	E. F. Nuezel	S. M. Hamill, Jr.	323 Plum St., Cincinnati, Ohio
Cleveland	2	Sept. 27, '07	363	D. E. Moat	S. R. Orem	Westinghouse Electric and Mfg. Co., Cleveland, Ohio
Columbus	2	Mar. 17, '22	86	D. E. Stafford	S. A. Martin	215 No. Front St., Columbus, Ohio
Connecticut	1	Apr. 16, '21	299	H. W. Sundius	A. G. Conrad	Yale University, New Haven, Conn.
Denver	6	May 18, '15	177	L. M. Robertson	Hubert Sharp	Mountain States Tel. and Tel. Co., Box 960, Denver, Colo.
East Tennessee	4	Sept. 2, '36	137	F. J. Stevens	J. H. Christensen	TVA, Power Bldg., Chattanooga, Tenn.
Erie	2	Jan. 11, '18	56	H. G. Moore	W. D. Bearce	4121 Sassafras St., Erie, Pa.
Florida	4	Jan. 28, '31	100	Stanley Warth	Joseph Weil	University of Florida, Gainesville, Fla.
Fort Wayne	5	Aug. 14, '08	80	G. C. Harvey	R. W. Clark	Magnavox Co., Fort Wayne, Ind.
Georgia	4	Jan. 14, '04	122	E. W. O'Brien	R. L. Williamson	Aluminum Co. of America, Atlanta, Ga.
Houston	7	Aug. 7, '28	141	N. F. Rode	H. P. Heafer	2023 South Blvd., Houston, Texas
Iowa	5	June 25, '29	81	K. R. Brown	L. A. Ware	University of Iowa, Iowa City, Iowa
Ithaca	1	Oct. 15, '02	55	J. P. Wood	H. G. Smith	Cornell University, Ithaca, N. Y.
Kansas City	7	Apr. 14, '16	128	A. T. Campbell	M. E. Bretschneider	Kansas City Power and Light Co., Kansas City, Mo.
Lehigh Valley	2	Apr. 16, '21	194	J. W. Mills	L. Z. Ludorf	119 No. Atherton Ave., Kingston, Pa.
Los Angeles	8	May 19, '08	507	F. C. Lindvall	L. F. Hunt	Box 351, Los Angeles, Calif.
Louisville	4	Oct. 15, '26	86	J. R. Smith	T. J. Borgman	Southern Bell Tel. and Tel. Co., Louisville, Ky.
Lynn	1	Aug. 22, '11	167	J. W. Lingary	W. R. Cox	General Electric Co., 920 Western Ave., Lynn, Mass.
Madison	5	Jan. 8, '09	72	R. R. Knoff		
Mansfield	2	Mar. 6, '39	77	C. P. Robinson	Wm. C. Bruckman	374 Sturges Ave., Mansfield, Ohio
Maryland	2	Dec. 16, '04	286	G. R. Page	M. W. Pullen	Johns Hopkins University, Baltimore, Md.
Memphis	4	May 23, '30	66	C. L. Osenbaugh	W. J. Fransioli, Jr.	Memphis Light, Gas and Water Div., Memphis, Tenn.
Mexico	8	June 29, '22	57	C. Santacruz	C. C. Jagou	Apartado 2966, Mexico City, Mexico
Michigan	5	Jan. 13, '11	398	S. M. Dean	M. B. Stout	University of Michigan, Room 274, Ann Arbor, Mich.
Milwaukee	5	Feb. 11, '10	286	E. W. Hatz	W. Richter	First Wisconsin National Bank Bldg., Milwaukee, Wis.
Minnesota	5	Apr. 7, '02	103	K. J. Mertz	W. H. Gille	Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Montana	9	June 24, '31	40	E. W. Schilling	Herold Murdock	Montana Power Co., 18 East Main, Bozeman, Mont.
Muscle Shoals	4	Feb. 18, '38	30	M. B. Clayton	E. H. Noedel	Box 1322, Wilson Dam, Ala.
Nebraska	6	Jan. 21, '25	45	D. J. DeBoer	B. E. Ellsworth	1018 South 34th St., Lincoln, Nebr.
New Mexico-West Texas	7	Mar. 7, '40	43	M. A. Thomas	O. F. Metz	Allis-Chalmers Manufacturing Co., El Paso, Tex.
New Orleans	4	Dec. 8, '33	132	B. P. Babin	F. E. Johnson	317 Baronne St., New Orleans, La.
New York	3	Dec. 10, '19	3,492	D. A. Quarles	C. S. Purnell	Westinghouse Elec. and Mfg. Co., 40 Wall St., New York, N. Y.
Niagara Frontier	1	Feb. 16, '25	207	E. B. Alexander	Wm. K. Parks	Westinghouse Elec. and Mfg. Co., Buffalo, N. Y.
North Carolina	4	Mar. 21, '29	101	H. B. Wolf	W. B. White	210 E. Sixth St., Charlotte, N. C.
North Texas	7	May 18, '28	181	G. N. Pingree	T. D. Thomas	Texas Power and Light Co., Dallas, Tex.
Oklahoma City	7	Feb. 16, '22	117	John Wallis	R. L. Jones	Southwestern Bell Tel. Co., Oklahoma City, Okla.
Philadelphia	2	Feb. 18, '03	750	W. B. Morton	A. C. Muir	Berwind-White Coal Mining Co., Philadelphia, Pa.
Pittsburgh	2	Oct. 13, '02	630	R. L. Dunlap	B. M. Jones	Duquesne Light Co., 435—6th Ave., Pittsburgh, Pa.
Pittsfield	1	Mar. 25, '04	197	S. T. Maunder	F. B. Nutt	General Electric Co., Pittsfield, Mass.
Portland	9	May 18, '09	196	J. A. Hooper	D. L. Brown	Portland General Electric Co., Portland, Ore.
Providence	1	Mar. 12, '20	95	W. C. Whitman	R. W. Herrick	General Electric Co., Providence, R. I.
Rochester	1	Oct. 9, '14	110	W. F. Cotter	C. F. Harris	Westinghouse Electric and Mfg. Co., Rochester, N. Y.
St. Louis	7	Jan. 14, '03	304	R. Meyerand	C. W. Schemm	General Electric Co., St. Louis, Mo.
San Diego	8	Jan. 18, '39	46	C. J. Nevitt	W. T. Johnson	Nevada-Calif. Electric Corp., El Centro, Calif.
San Francisco	8	Dec. 23, '04	543	M. S. Barnes	C. E. Baugh	Pacific Gas and Electric Co., San Francisco, Calif.
Saskatchewan	10	Oct. 14, '25	10	M. L. Haynes	J. R. Young	1945 Scarth St., Regina, Sask., Canada
Schenectady	1	Jan. 20, '03	484	D. E. Chambers	T. T. Woodson	General Electric Co., Research Lab., Schenectady, N. Y.
Seattle	9	Jan. 19, '04	202	K. L. Howe	C. S. Alger	Puget Sound Power and Light Co., Seattle, Wash.
Sharon	2	Dec. 11, '25	120	M. L. Manning	J. G. Mitchell	Pennsylvania Power Co., Sharon, Pa.
South Bend	5	Feb. 26, '41	52	D. C. Jackson, Jr.	F. M. Henderson	Indiana and Michigan Electric Co., South Bend, Ind.
South Carolina	4	Mar. 2, '40	50	S. R. Rhodes	N. H. Colt	South Carolina Electric and Gas Co., Columbia, S. C.
South Texas	7	May 23, '30	48	R. W. Warner	G. E. Schmitt	Lower Colorado River Authority, Austin, Tex.
Spokane	9	Feb. 14, '13	84	G. L. Lane	H. E. Mellrud	Washington Water Power Co., Spokane, Wash.
Springfield	1	June 29, '22	51	H. D. Griffith	I. Creaser	76 Cortland St., Springfield, Mass.
Syracuse	1	Aug. 12, '20	103	V. J. Brown	S. C. Osborne	200 Rugby Road, Syracuse, N. Y.
Toledo	2	June 3, '07	80	K. C. Davis	W. M. Campbell	2145 Central Grove Ave., Toledo, Ohio
Toronto	10	Sept. 30, '03	363	O. W. Titus	A. R. Zimmer	University of Toronto, Toronto, Ont., Canada
Tulsa	7	Oct. 1, '37	90	J. V. McGinity	O. A. Hass	Allis-Chalmers Manufacturing Co., Tulsa, Okla.
Urbana	5	Nov. 25, '02	68	L. B. Archer	G. R. Peirce	Univ. of Illinois, 212 Electrical Engineering Lab., Urbana, Ill.
Utah	9	Mar. 9, '17	72	H. H. Krueger	J. A. McDonald	General Electric Co., Salt Lake City, Utah
Vancouver	10	Aug. 22, '11	91	J. A. Tames	F. V. Knight	1796 West 5th Ave., Vancouver, B. C., Canada
Virginia	4	May 19, '22	137	L. Saunders	C. L. Crosby	Richmond Trust Bldg., Richmond, Va.
Washington	2	Apr. 9, '03	491	F. M. Defandorf	F. W. Willcutt	Potomac Electric Power Co., Washington, D. C.
West Virginia	2	Apr. 9, '40	54	H. P. Musser	W. J. Blake	119 Wyoming St., Charleston, W. Va.
Wichita	7	Sept. 16, '37	64	C. V. Waddington	H. B. Margrave	Kansas Gas and Electric Co., Wichita, Kans.
Worcester	1	Feb. 18, '20	65	G. M. L. Sommerman	T. R. Holton	American Steel and Wire Co., Worcester, Mass.
Total	72					

Of Current Interest

National Defense

Four-Year Power Expansion Program Proposed by FPC

"To provide adequate power supply for the Defense program in 1943, 1944, 1945, and 1946," the Federal Power Commission presented to the President in July a program calling for the installation of nearly 13,500,000 kw of new generating capacity over the four-year period. The Commission recommends that a subsidiary of the Reconstruction Finance Corporation be set up to place and finance orders for the necessary generating equipment.

The 13,500,000 kw of new generating capacity is divided roughly into 8,600,000 kw for steam, chiefly for private companies, and 4,900,000 kw for hydroelectric power, mostly government-owned, 900,000 kw of which is assigned to the St. Lawrence Seaway project. Presented with the report was a tentative list of projects, a summary of which appears in the accompanying tabulation.

Orders for generating equipment sufficient to keep manufacturers operating at full capacity for the next five years should be prepared at once and financial commitments made for units to be completed in 1943 or 1944, the Commission states. Such orders are to be based on the Commission's program for location of new capacity, subject to modification by the Office of Production Management. Funds advanced for this purpose by the RFC are expected to average between $150,000,000 and $200,000,000 a year. Both publicly and privately owned utilities will be given opportunity to undertake the commitment either directly or on a lease-purchase basis of units provided for their systems. The Commission is expected to work out modifications of the plan in conference with representatives of individual utilities.

Expenditures averaging about $170,000,000 annually are expected to be made by the United States Corps of Engineers, the Bureau of Reclamation, the Tennessee Valley Authority, and other agencies, for the construction of dams, reservoirs, and powerhouses for the hydroelectric projects, exclusive of the cost of generating equipment. The cost of steam-electric projects, also exclusive of equipment, is expected to average between $75,000,000 and $100,000,000 a year, and "may be expected to come largely from private sources."

Summary of FPC Program for New Generating Facilities 1943–46

Region	States	Steam Electric			Hydroelectric		Gross Total Kw
		No. Systems	No. Plants	Kw	No. Plants	Kw	
I	Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, eastern Pennsylvania, New Jersey, Delaware, most of Maryland, and the District of Columbia	19	25	2,500,000	11	1,222,000	3,722,000
II	Western Pennsylvania, northwestern Maryland, West Virginia, Ohio, Michigan, major parts of Indiana, Kentucky, and southwestern Virginia	16	26	2,300,000	15	573,000	2,873,000
III	Eastern and northern Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, and eastern Mississippi	11	18	1,075,000	12	1,129,000	2,204,000
IV	Wisconsin, Illinois, Iowa, northeastern Missouri, most of Minnesota, small parts of northeastern Nebraska, eastern South Dakota, and northern Indiana	13	21	1,805,000	1	15,000	1,820,000
V	Louisiana, Arkansas, Oklahoma, Texas, New Mexico, and western Mississippi	7	8	365,000	13	431,000	796,000
VI	North Dakota, South Dakota, western Minnesota, eastern Montana, Wyoming, Colorado, Kansas, southwestern Missouri, small part of Iowa, major part of Nebraska	4	4	95,000			95,000
VII	Washington Oregon, Idaho, Utah, major part of Montana	5	6	325,000	5	990,000	1,315,000
VIII	Nevada, California, Arizona	3	3	210,000	13	530,500	740,500
Totals		78	111	8,675,000	70	4,890,500	13,565,500

The Commission's report points out that the resulting annual output of approximately 2,500,000 kw of new steam-electric and 1,000,000 kw of new hydroelectric generating units will insure power supply for the maximum Defense effort as presently conceived, assuming approximately 30 per cent displacement of normal loads.

Responsibility for Defense power planning including the FPC program, has been vested in a new agency created by the Office of Production Management and headed by J. A. Krug, former manager of power for the Tennessee Valley Authority, as Defense power co-ordinator. The new unit, which will work closely with the FPC, also has a consulting board on which both publicly and privately owned utilities are represented. Among these consultants are: Philip Sporn (A'20, F'30) American Gas and Electric Corporation; J. Moore, Electric Bond and Share; E. W. Morehouse, Associated Gas and Electric Company trustees; K. M. Irwin and Constantine Bary (A'25) Philadelphia Electric Company. John C. Parker (A'04, F'12) vice-president, Consolidated Edison Company of New York, Inc., and Fred Schaff, Superheater Company, have been appointed to the staff of the OPM power division to handle priorities.

Three members of the FPC staff also have been appointed to work with the OPM power division on the Defense power program. W. S. Youngman, general counsel for the Commission, G. H. Buck, engineer in charge of the power supply section, FPC defense power staff, and W. E. Caine, rate expert, will act as liaison between the two agencies.

Power Supply and the Aluminum Situation

A recent press release from the United States Chamber of Commerce, Washington, D. C., asserts that with current expansions of electric utility systems, the power outlook for the country as a whole this year indicates that generating capacity available will exceed peak demands by a margin of nearly 30 per cent, except for reductions in effective capacity resulting from the spring drought, particularly in the south eastern states and along the eastern seaboard. It is pointed out that "the placing of additional orders for generators to parallel the stepping-up of defense operations cannot possibly result in delivery before 1943 or 1944," because of the priority given to steam turbine production for naval vessels as compared with the needs in private utility plants. The belief is expressed that most of the new power demands that may be developed during the next 18 months will have to be met through a more efficient utilization of present capacity.

Briefly referring to the relationship between electric power and aluminum production, the Chamber of Commerce release points out that power to produce aluminum

heretofore has never been a service or responsibility of private utility companies, since the aluminum companies generated their own power until they began to purchase power from the Tennessee Valley Authority.

In an effort to secure first-hand information concerning the presently confused question of adequacy of aluminum supply for defense purposes, the National Association of Manufacturers recently made a nation-wide telegraphic survey of 20 airplane and other defense production centers. According to NAM, quoting its president Walter D. Fuller, the survey "indicates that production and delivery of vital armament equipment has not been delayed to date by a shortage of the white metal," but that "there is no assurance that such a shortage might not develop in the future as the defense program expands, and the mere finding that there is no current shortage should not be interpreted as an effort to discourage collection of aluminum household utensils or other methods of conserving the civilian use of this much needed metal."

The survey indicated that the larger fabricating companies, being more familiar with priorities procedure and with the necessity of provision for advance stock, have been able to maintain adequate stocks for current orders, whereas some of the smaller concerns failed to obtain proper priority ratings and consequently are experiencing difficulties in obtaining aluminum deliveries. The survey showed that practically no aluminum is now being obtained by nondefense industries, such manufacturers either laying off employees or turning to substitute metals or plastics.

FPC CREATES SOUTHEASTERN POWER GRID

The power shortage in the southeastern United States, brought about in the early summer by abnormally low rainfall and tremendously increased power requirements for defense industries in that area, caused the Federal Power Commission to make the first use of its emergency powers. Declaring an emergency to exist, the Commission has ordered a series of interconnections among power companies, municipal plants, and REA co-operatives, and urged curtailment of the use of electricity for domestic and commercial purposes and in nondefense industries. Completion of the interconnections, some of which require as much as six months to construct, will make available to the 17 states affected additional capacity estimated at 200,000 kw. The interconnections were declared by the Commission to be the result of a series of studies and conferences on the part of the Commission with publicly and privately owned utilities to devise ways of meeting the Southeastern power emergency.

Increased rainfall during July relieved the shortage to some extent, but a program of power conservation for the region was launched officially by the Office of Production Management to secure more power for defense production, notably aluminum. To stimulate conservation, the United States Army Air Corps approved a plan to dedicate Army fighting planes to communities which save their assigned quotas of power. Since the aluminum required for a large bomber takes about 100,000 kilowatt-hours to produce, a community which saves that amount of power will in effect have contributed enough to build the plane. Awards will be made on a sliding scale to enable small communities as well as large to participate.

MORE POOLS PROPOSED

Two more power pools to tap reserves for aluminum production were announced by Defense Power Co-ordinator J. A. Krug of the OPM as in process of formation late in July. One includes New York, eastern Pennsylvania, New Jersey, and New England for the production of 150,000,000 pounds of aluminum annually in upper New York State; the other includes power from Arkansas, Oklahoma, Texas, Louisiana, Missouri, and Kansas, for production of 100,000,000 pounds of aluminum in Arkansas and for magnesium capacity in Texas. Both are made possible largely by the voluntary co-operation of the utilities involved, Mr. Krug said.

ALUMINUM GETS POWER PRIORITIES

Acting for the stated purpose of insuring power supply for defense production of aluminum, the Federal Power Commission on June 28 directed the Carolina Aluminum Company to reduce contract deliveries of electric energy to the Duke Power Company, following reports that such deliveries threatened to increase the prevailing power shortage in the Southeast by drawing down water in reservoirs. On request of the Aluminum Company of America, the Commission on July 2 authorized the Niagara Falls Power Company to supply an additional 500 kw of power immediately to increase defense production of aluminum in New York State. The additional power will be provided from the temporary emergency diversion by the United States of an additional 5,000 cubic feet of water per second from the Niagara River. The additional diversion, authorized by the Commission immediately following Senate approval on June 12 of a special agreement with Canada, provides 64,100 kw of power. Subsequently the Commission allotted the remainder of this additional power to 15 defense industries in the Buffalo-Niagara area, increasing the Aluminum Company's allotment to 1,200 kw. If any of the industries affected are unable to make full use of their allotment of emergency defense power for two consecutive months, the Commission may reallot the unused portion.

TVA TO OPERATE ALCOA POWER SYSTEM

The five-dam hydroelectric system of the Aluminum Company of America on the Little Tennessee River will be operated by the Tennessee Valley Authority, under the terms of a contract signed August 15. Announcing the contract, TVA states that it "will not assume ownership of the company's plants but will direct and control their operations, and will integrate them with its own extensive system of dams in such a way as to obtain the maximum public usefulness of the water in the entire Tennessee River watershed." The contract also provides for the acquisition by TVA of the Fontana dam site, which the company has owned for 30 years, and which the TVA proposes to develop at an estimated cost of $50,000,000. Construction of the dam has been approved by the Office of Production Management as a defense necessity, and will begin as soon as Congress provides the necessary funds.

Grand Coulee Power Will Supplement Bonneville for Defense Industries

Scheduled to start operation in August, the first of three identical 108,000-kw generators at Grand Coulee Dam will begin to deliver power to the newly created defense industries in the Northwest, supplementing Bonneville Dam, which is reported to be operating at full capacity. Two more generators are being assembled at the West power house, for operation in December 1941 and spring 1942 respectively. When completed, Grand Coulee will have 18 generators of the 108,000-kw capacity, the largest yet built in the United States; a total capacity of 1,620,000 kw under favorable water conditions.

Industries to use the power from Bonneville and Grand Coulee have been brought to the region by the Defense effort. Production of aluminum beginning in August at the Longview, Wash., plant of the Reynolds Metals Company is expected to use 60,000 kw by May 1942. Five plants of the Aluminum Company of America, Vancouver, Wash., now use 172,500 kw. These, with three government-owned plants in the area, which are scheduled for completion in about 18 months, will bring aluminum production in the Pacific Northwest to about 400,000,000 pounds annually, an amount which represents about two-thirds of the estimated 1942 demand for the Pacific Coast, about one-fourth of anticipated United States production for that year. Other defense industries now drawing power from Bonneville-Grand Coulee are the Pacific Carbide and Alloys Company and the Oregon Shipbuilding Company. The Pennsylvania Salt Manufacturing Company (chlorate for explosives), Electrometallurgical Company (calcium carbide and eventually ferro-alloys for steel), and a government built and leased magnesium plant at Spokane are expected to start operations during 1942. Efforts currently are being made to secure fabricating plants for the area.

New Steam-Electric Units Ordered

Alabama Power Company has ordered a 60,000-kw turbogenerator from General Electric Company, to be installed in its Gorgas Number 2 steam plant. This unit, the second of its size to be installed in this plant, is expected to be ready for operation May 1, 1943.

Cleveland Electric Illuminating Company has ordered a 50,000-kw turbogenerator, also from General Electric, for installation at its Avon power plant. Scheduled for operation in the fall of 1943, the new unit is said to be "100 per cent for National Defense." Two generators, with a total dependable capacity of 144,000 kw, are now under construction for the company's Lake Shore plant. The company is spending approximately $13,300,000 this year for new facilities.

Union Electric Company of Missouri has ordered a second 80,000-kw generator to be installed at its Venice Number 2 power plant now under construction at Venice, Ill. The first 80,000-kw unit is now on order for delivery in the fall of 1942; delivery on the second is expected in June 1943. Both are being built by the General Electric Company.

The new plant will also contain two 40,000-kw units, now under construction at Allis-Chalmers Manufacturing Company. The new plant and modernization of another plant will provide an increase of 265,000 kw in capacity, or about 40 per cent, to the Union Electric system. This plant is the objective of one of the inspection trips offered to those who attend the AIEE South West District meeting in St. Louis, October 8–10, 1941.

Minnesota Power and Light Company will install a new 33,500-horsepower generating unit at the company's Duluth, Minn., steam plant, doubling the capacity of the plant. The unit will be completed in 1943. A 17,000-horsepower steam electric plant is now under construction by the Superior Water, Light, and Power Company, Superior, Minn., to be completed in 1942. The two units will provide an additional 50,000 horsepower for the interconnected transmission systems of the companies.

FPC Hearing Scheduled on Pit River Development

The Pacific Gas and Electric Company has notified the Federal Power Commission of its unwillingness to accept the conditions imposed with the licensing of the Cresta and Pulga developments on the north fork of the Feather River and its intention to begin construction instead on a previously planned new development on the Pit River, which would utilize equipment and materials previously ordered for the Feather River plants. On advice of the Commission, the company filed a declaration of intention for the Pit River project, and public hearings were set for August 18. Subsequently the Commission again rescinded the license for the Cresta and Pulga plants (*EE, Apr. '41, p. 188–9; July '41, p. 355*). Special conditions imposed with the license for the Cresta and Pulga plants required the approval of the Commission for any increase of generating capacity which would make available more than 5,000 kw additional capacity at any one plant or from any one source or a total of 20,000 kw additional capacity; and imposed other restrictions relating to the company's Big Bend development, also on the north fork of the Feather River.

Commercial Aviation in the Defense Picture

Shipments of heavy industry products by air express showed a gain of 108 per cent for April 1941 over April 1939, according to recently reported statistics from the Air Express division of Railway Express Agency. The largest increase, 287 per cent, was shown by shipments to and from airplane plants, chiefly subassemblies, shortages, tools, instruments, and drawings. A large proportion of all express carried from eastern centers to the west coast consists of shipments from parts manufacturers to the large aircraft shops, the report shows. Regular daily scheduled shipments keep production lines moving; chartered planes handle emergency consignments.

One instance cited for the use of air express in transporting heavy shipments to speed the defense program was that of six circuit breakers to be used in a new defense plant. Weighing a total of 2,600 pounds, the six circuit breakers were loaded by the manufacturer in Philadelphia onto a regular DC-3 air liner ferried from New York for the purpose; flown to New York, and sent on successive regular trips by air express to their destination in Detroit. The entire shipment was delivered the same day it left Philadelphia.

AIR FREIGHT UNIT FORMED

Competing with the United States Air Mail and the Air Express division of Railway Express Agency, United States Freight Company has formed a subsidiary, Universal Air Freight Company, which will pick up shipments at New York and Detroit for direct air delivery at Chicago, Cleveland, Dallas, Denver, Des Moines, Kansas City, Los Angeles, Minneapolis, Omaha, St. Paul, and Tulsa. The company will carry a one-pound package from New York to Los Angeles in 16 hours for 65 cents. The air mail cost of similar service is 95 cents. Packages under 15 pounds will be picked up by Postal Telegraph boys for Universal at no extra charge to the customer.

MORE AIRPORTS

Funds have been voted by Congress to complete the Civil Aeronautics Authority's program of building and improving 250 civil airports of emergency military value, and to carry out improvements at 149 additional airports. An appropriation of $94,978,000 has been voted for the CAA and expenditures of about $40,000,000 toward the program also will be made by the Works Progress Administration. The airport sites will be chosen for their military value by a board consisting of the secretaries of War, Navy, and Commerce.

PLANE PRIORITIES

Conflict between Army demands and the currently growing boom in commercial air transport is resulting in studies by Congress and by the Civil Aeronautics Authority on civil air transport needs. Although estimates indicate that the transport lines could use from 100 to 150 more transports, attempts to get them have conflicted with Army and aid-to-Britain needs. If commercial lines can prove their importance in the defense program, they may be able to get priority on planes. Air transport to Latin America is regarded as vital to hemisphere defense, but development of American-controlled lines to replace German and Italian airlines in South American countries toward which diplomatic progress has been made, is reported to be held up by lack of equipment. The Army is reported to oppose letting domestic commercial lines have the equipment they want, claiming that much domestic transport can be shifted to railroads or highway. Commercial aviation men, however, see the industry as a reservoir of trained men and equipment; propose that the commercial lines be allowed to accumulate 500 planes, all of which could be taken over by the Government in any sudden emergency.

The foregoing, and many other current trends and developments, give emphasis to the recommendations made by Grover Loening in his article "Future Trends in Air Transportation" (*EE, Jan. '41, p. 57–63*).

Engineering Defense Training Broadened in Scope

The Engineering Defense Training program sponsored by the United States Office of Education has been broadened to include defense training in physics, chemistry, and industrial management. Institutions granting degrees in those subjects are now eligible to participate in the program, under which short intensive courses are given to present and prospective workers in defense industries. Inclusion of nonengineering institutions was authorized in a bill approved by Congress July 1, 1941, appropriating an additional $17,500,000 to carry on the educational program. The original program was financed by a $9,000,000 appropriation approved October 9, 1940, of which $8,795,171 had been allocated by June 30, 1941. Under its provisions approximately 2,300 courses have been set up for some 130,000 students by 144 engineering colleges in 47 of the United States, the District of Columbia, and Puerto Rico. (See *EE, Nov. '40, p. 478; Dec. '40, p. 521; Feb. '41, p. 92.*)

Three new members of the advisory committee have been appointed to consult on the new aspects of the program, the title of which has been changed to "Engineering, Science, and Management Defense Training". The new members are Homer L. Dodge, dean of the graduate school, University of Oklahoma, who will advise on the training of physicists; Clare E. Griffin, dean of the school of business administration, University of Michigan, who will advise on the training of production supervisors; and N. W. Rakestraw, professor of chemistry, Brown University, who will advise on the training of chemists.

Under a recently appointed subcommittee on education of the Joint Army and Navy Committee on Welfare and Recreation, plans are being developed for an educational program for men in Army and Navy service, according to an announcement from the American Council on Education. A number of colleges and universities adjacent to Army camps and Navy stations are planning cooperative programs either on a voluntary basis, or under the Engineering Defense Training program, the announcement states.

Radio, Electrical-Appliance Makers Meet Defense Restrictions

Among industries sharply affected by Defense priorities on materials and production, radio manufacturing and production of electrical appliances are conspicuous. Aluminum is being rationed currently to the radio industry at about 110,000 pounds per month —approximately one-third of its former consumption, with further reduction to about 70,000 pounds anticipated by the end of the year. Unable to get civilian priorities on aluminum, the industry has turned its research abilities to development of substitute materials; has found replacements for aluminum in all uses except for electrolytic capacitors. However, some of the substitutes are in turn being rationed and further substitutes are required.

With 1941–42 production of radio sets estimated at approximately 70 per cent of 1940 levels, the industry is making changes in manufacturing and merchandising policies

which are said to include greater emphasis on high-priced sets and combinations (FM, phonograph), reduction in number of models, attempts to stabilize prices at higher levels, dealer-emphasis on repair and modernization services.

Meanwhile, defense orders, currently estimated at about 15 per cent of industry output and rapidly increasing, are regarded as the industry's lifeline. To date, most of these have gone to large manufacturers, but the trend is toward much wider distribution through the smaller firms. Reporting to stockholders in May, David Sarnoff, president of RCA, declared that defense orders received by that company to date totaled $36,500,000, and pointed out that work on some orders had been divided among as many as 109 subcontractors.

Manufacturers of electrical appliances face not only shortages of materials but reductions in volume imposed by the Office of Price Administration and Civilian Supply to save on consumption on metals and release labor and equipment for defense production. Such reductions are not yet decided but are expected to range between 30 and 50 per cent. With sales for the first six months of 1941 reaching all-time highs, cuts of from 33 per cent in electric washers, 42 per cent in refrigerator units, and 53 per cent in stoves could be made without bringing sales of any of these below 1939 levels, it is reported. In the manufacture of all major appliances, impending shortages of aluminum and other important metals for non-defense use already have resulted in shifts to available substitutes, and undoubtedly will require further and more drastic shifts. No substitute has been found as yet for the nickel required in the primary resistor of electrical heating devices; manufacturers are saving nickel for this purpose by substituting other materials elsewhere.

Electrical Manufacturers' Liaison Committee Formed

A committee of 24 representatives of the electrical manufacturing industry has been appointed to work with the Office of Production Management on defense problems. Typical of such problems are: temporary modifications of Federal specifications to permit use of substitutes, the conservation and substitution of materials, simplified practices, allocation of production capacity, and standardization of production. Attention will be especially directed toward spreading government purchases, through increased subcontracting and getting small plants to take on more direct orders.

Six members of the committee have been designated as a steering committee to work with the chief of the equipment and supplies branch of OPM's procurement division. These are:

W. J. Donald, National Electrical Manufacturers Association; Leonard Kebler, Ward Leonard Electric Company, Mt. Vernon, N. Y.; J. P. Shelley, Metropolitan Electric Manufacturing Company; W. B. Sprackling, Anaconda Wire and Cable Company; George Thomas, Jr., Thomas and Betts Company, Elizabeth, N. J.; George P. Hessler, Graybar Electric Company, New York, N. Y.

Other members of the committee are:

H. B. Blood, Norge division, Borg-Warner Company, Detroit, Mich.; C. L. Collens (A'07, M'40) Reliance Electric and Engineering Company, Cleveland, Ohio; Frederick Eisman, Revere Electrical Company, New York, N. Y.; Ralph Kelly, Westinghouse Electric and Manufacturing Company, New York, N. Y.; L. E. Latham, E. B. Latham and Company, New York, N. Y.; F. W. Magin, Square-D Company, Detroit, Mich.; R. W. McChesney (A'20, M'28) National Electrical Contractors Association; J. W. McNair (A'25) American Standards Association; Everett Morss, Simplex Wire and Cable Company, Cambridge, Mass.; J. M. Newton (A'18, F'37) Oakes Electric Supply Company, Holyoke, Mass.; Matthew Porosky, Eagle Signal Corporation, Boston, Mass.; A. C. Prange, General Electric Supply Corporation, Bridgeport, Conn.; C. A. Scott, Rome Cable Corporation, Rome, N. Y.; E. O. Shreve (A'06) General Electric Company, Schenectady, N. Y.; D. M. Simmons (A'22, F'28) General Cable Corporation, New York, N. Y.; P. J. Smith, American Society for Testing Materials; C. E. Swartzbaugh, Swartzbaugh Manufacturing Company, Toledo, Ohio; Walter Williamson, Westinghouse Electric Supply Company, New York, N. Y.

Appointment of this committee is part of a general program aiming at a working relationship between government and industry, on a commodity basis. About 30 committees are expected to be appointed, each paralleling a commodity unit in the OPM. Subcommittees and temporary industry groups also will be appointed to handle details and special problems. The function of the committees is purely advisory.

Unit for Scientific Research Headed by Vannevar Bush

To co-ordinate all scientific activities connected with National Defense, the Office of Scientific Research and Development has been created within the Office of Emergency Management by executive order of the President. The new office will serve as liaison agency for several scientific groups which have been working independently. It also is authorized to "initiate and support" research programs for the production of new defense materials and methods, and medical research programs having defense value. Funds for such programs will be provided by Congressional appropriation. Previous groups of this type have had advisory powers only.

Doctor Vannevar Bush (A'15, F'24) president of the Carnegie Institution of Washington and until now chairman of the National Defense Research Committee, has been appointed to head the Office of Scientific Research and Development. President James B. Conant of Harvard University succeeds Doctor Bush as chairman of the National Defense Research Committee which will be one of the principal agencies for carrying on activities initiated by the new body. Other existing agencies which will report through Doctor Bush's organization include the National Advisory Committee for Aeronautics and the Health and Medical Committee established by the Council of National Defense; distinctly Defense activities of such established Government bureaus as the Bureau of Mines and National Bureau of Standards also will come under its control.

The Office of Scientific Research and Development will work closely with the Office of Production Management, the Office of Civilian Defense, the War and Navy Departments, in finding useful scientific methods, devices, and materials, which those agencies can put into use. Provision also is made for co-operation with British research bodies.

Defense Unemployment

The shift from peace-time production of consumer goods to concentration on defense industries in the United States is producing its own brand of unemployment which, according to Price Administrator Leon Henderson, may affect some 2,000,000 or more workers. Consumer-goods industries are faced with difficulty in obtaining raw materials, as a result of defense priorities, and are likely to be compelled to reduce operations drastically. Unemployment will result, at least during the adjustment period. The household equipment industry is among those already seriously affected, along with silk, automobiles, gasoline distribution, home building, and other consumer industries. Some reports currently in circulation indicate that such consumer goods as radios and certain electrical appliances may be completely out of production within the year.

When the shift to armament economy is completed, it is expected that increased activity will create a growing demand for workers, at least for the duration of Defense production. An example of efforts to meet the immediate problems is found in the Office of Production Management's program to put the silk industry back at work using substitute materials. Substituting materials not needed for defense purposes or finding a way to use plant and machinery in the defense program seem to be the chief solutions open at present to manufacturers of peace-time products.

Allis-Chalmers Creates Priorities Department. A new administrative department, known as "priorities management" has been set up by the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., to handle details relating to priorities. Functions of the department will be to present company problems to government agencies, co-ordinate information for other departments of the company, help determine shop schedules when jobs with the same priorities rating conflict.

Positions to Be Filled Through Civil Service Examination

Notice of the following positions, which will be filled through civil service examinations, is published here as a service to members of the Institute. Application forms and full information as to requirements for examinations may be obtained from the secretary of the Board of United States Civil Service Examiners at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D. C. Applications will be accepted until further notice.

Industrial Specialists. The Government continues its search for specialists in all branches of industry and business. The Federal Civil Service examination for industrial specialist, announced on July 7, has been amended to remain open for receipt of applications until further notice. The National Defense program needs men with experience in one or more of the following fields: Iron and steel; nonferrous metals; machine tools; ordnance; aircraft, marine, and automotive equipment; railroad repair shops; radio and other electrical equipment, supplies and apparatus; textiles; forest products; paper; printing and publishing; chemicals and allied products; plastics; petroleum and coal prod-

acts; rubber products; stone, clay, and glass products; leather and its manufactures; food and kindred products. Salaries range from $2,600 to $5,600 in the various grades. No written examination is given.

Naval Architects and Marine Engineers. Revised examinations have just been announced by the Civil Service Commission for persons qualified in all branches of naval architecture and marine engineering. Persons are particularly needed for filling positions in the assistant and associate grades ($2,600 and $3,200 a year, respectively). However, naval architects or marine engineers qualified to fill all the grades (salaries range as high as $5,600 a year) are urged to apply at once, although applications will be accepted until June 30, 1942. The Commission will not accept applications from those persons who successfully passed the examinations for Naval Architect or Marine Engineer positions under the terms of Announcements No. 50, 51, 111, and 112 of 1940, which closed on June 30, 1941, unless they are now eligible for rating in a higher grade. Persons who have been placed on the Commission's employment list, as a result of the previous examinations will be retained on the new list to be established as a result of the examinations just announced. The experience and education requirements have been modified. For instance, experience need no longer be in any specific branch. Complete substitution of experience is allowed for the four years of college study in engineering or naval architecture. However, if more than two years of experience is substituted in this way, it must have been in strictly technical work and of such scope as to indicate a person's professional knowledge of the fundamentals of engineering or naval architecture. In addition to this education or experience, appropriate professional naval architectural or engineering experience is required, and some of this experience must have demonstrated outstanding professional attainment in the field. Persons who have done graduate study in engineering or naval architecture may substitute three years of such study for the general experience required. Applicants who have completed a four-year college course in either engineering or naval architecture may also substitute certain shipyard experience for the general experience. A maximum of two years as journeyman or helper in a shipyard in any of the following trades may be utilized in the substitution: (1) for the naval architect—loftsman, shipfitter, template maker, shipjoiner, shipyard estimator, and ship draftsman; (2) for the marine engineer—boilermaker, patternmaker, pipefitter, machinist, electrician, shipyard estimator, or ship machinery draftsman.

Photogrammetric and Topographic Engineering Aids. Persons trained in engineering again are called upon for Government service. An examination has just been announced by the Civil Service Commission for engineering aids in two fields: photogrammetry and topography. Salaries range from $1,620 to $2,600 a year. Persons are particularly needed in the three lower grades (paying $1,620 to $2,000) in the field of photogrammetry. However, any person qualified for any of these positions is urged to file his application at once with the Commission's Washington office where it will be rated as soon as practicable after receipt. Applications will be accepted until June 30, 1942. Engineering aids appointed from this examination will perform engineering work in photogrammetric, geodetic, hydrographic, topographic, or cadastral surveying. They will plot survey notes or control points, and project and check scales of photographs. The operation of laboratory apparatus or survey instruments will also be a part of the work. A written test will not be given; competitors will be rated on their education and experience. Although the completion of 14 units of high-school study is a basic requirement applicants may substitute an additional six months of engineering experience for that education. In addition they must have had responsible civil engineering experience including some work in the optional branch selected. Persons who have had the required civil-engineering experience but who have not had the specialized work in one of the optional branches may also qualify for some of the positions provided they have successfully completed an approved defense training course in photogrammetry and aerial photographic mapping, or in topographic mapping and closely related subjects. A number of substitutions are provided for the general civil-engineering experience. Under certain conditions college study in any branch of engineering, in physics, chemistry, mathematics, or geology may be used to fill a portion of the experience requirement. Persons who have studied in night school or done part-time day study may also be permitted to utilize that study for a portion of the experience.

Education • • •

Engineering Experiment Station at Arizona. The establishment of an engineering experiment station for the purpose of research into problems of particular interest in the Southwest, has been voted by the board of regents of the University of Arizona. Members of the faculties of the colleges of engineering and of mines have been appointed to various positions on the staff, among them J. C. Clark (A'09, M'21), electrical engineer, and O. H. Polk (A'35), associate electrical engineer.

High-Voltage Generator Set Up at NYU. A high-voltage surge generator capable of generating 350,000 volts has been constructed at the New York University college of engineering by Ralph E. Armington (Enrolled Student) of Medford, Mass., under the supervision of Professor Harold Torgersen (A'31, M'39). The generator is the second unit in a newly established high-voltage laboratory at the college. The first unit was a high-voltage transformer installed last fall when the laboratory was opened. The new apparatus will be used in high-voltage research for the testing of insulating materials and insulators. It has been designed and constructed chiefly for the use of graduate students and research engineers, but will be used also for the study of problems presented by industrial laboratories. With Professor Philip Greenstein (A'29) Professor Torgersen has developed a high-speed high-voltage cathode-ray oscillograph to be used in connection with the surge generator.

General Electric Awards Steinmetz Scholarships. A General Electric Company employee, and the son of an employee of the affiliated Elmira Foundry Company, are the 1941 winners of the Charles P. Steinmetz Memorial Scholarships established by the company in 1924. Both will enter the electrical engineering course at Union College in Schenectady, N. Y., this fall. They are E. L. Bates, Jr., who is employed in the blueprint department, Pittsfield, Mass., and A. J. Taggi, son of Anthony Taggi, a molder in the Elmira Foundry Company, Elmira, N. Y.

Westinghouse Makes War Memorial Awards. Sons of five employees of the Westinghouse Electric and Manufacturing Company have been selected as the 1941 winners of the War Memorial Scholarships established in 1919 by the company in honor of its 5,000 employees who served in the World War. Candidates must be either sons of Westinghouse employees or young workers themselves, and winners were chosen on the basis of competitive examinations held in 21 cities, with 60 candidates participating. The awards provide $500 a year to be used in technical courses at colleges chosen by the recipients. This year's winners, their selected colleges, and courses of study are:

A. W. Kimball, Jr., Purdue University, chemical engineering; J. W. Hines, Carnegie Institute of Technology, electrical engineering; C. H. Smith, Jr., Massachusetts Institute of Technology, electrical engineering; W. E. Keene, Carnegie Institute of Technology, management engineering; and R. E. Brueckmann, Princeton University, electrical engineering.

Industry • • • •

Electric Energy Production and Capacity Reach Highs in 1940

The 1940 production of electric energy in the United States exceeded the previous all-time record reached in 1939 by more than 14,600,000,000 kilowatt-hours, or 11.2 per cent according to a recent report of the Federal Power Commission. Installed capacity of electric generating plants at the end of 1940 likewise reached a new high of 41,638,956 kw, a net increase over 1939 of 1,321,032 kw or 3.3 per cent.

The total production for all types of prime movers for 1940 was 144,984,565,000 kilowatt-hours. Privately owned utilities produced 127,642,231,000 kilowatt-hours from a total installed capacity of 35,500,651 kw, and publicly owned plants produced 17,342,334,000 kilowatt-hours from a total installed capacity of 6,138,305 kw, the report shows.

The increased utilization of electric energy during 1940 is reflected in the higher plant factor which, the report shows, increased to 40.3 per cent from 37.5 per cent in 1939. The plant factor shown in tables in the report is the ratio of the actual output in kilowatt-hours to the potential output on the basis of 100 per cent use of the installed capacity for every hour in the year. The installed capacity was assumed to be the capacity in service at the end of the preceding year plus one-half of the increase during the year in question.

Comparison of production of electric energy and capacity of generating plants for 1940 and 1939 is shown in the table at the bottom of the page, taken from the report.

Although the total capacity in service at the end of 1940 increased 1,321,032 kw over the preceding year, the total number of generating plants decreased from 4,126 in 1939 to 4,109 in 1940, the report shows. The total number of privately owned plants reporting to the Commission decreased from 2,925 in 1939 to 2,864 in 1940, while the

	Production 1,000's of Kw-Hr		Capacity (Kw)		Plant Factor (Per Cent)	
	1940	1939	1940	1939	1940	1939
Hydro	47,752,627	44,021,631	11,675,300	11,415,165	47.1	44.7
Steam	95,874,853	85,006,941	29,019,102	28,046,948	38.2	35.1
I.C.	1,557,285	1,307,478	944,554	855,811	19.7	18.3
Total	144,984,565	130,336,050	41,638,956	40,317,924	40.3	37.5

total number of publicly owned plants increased from 1,201 to 1,245 during the same interval.

The number of establishments and number of plants are shown by class ownership in a table in the report as follows:

Class of Ownership	Number of Establishments	Number of Plants
Total all classes of ownership	1,696	4,109
Privately owned		
Electric utilities	561	2,676
Mining & manufacturing	130	163
Railways and railroads	17	25
Subtotal	708	2,864
Publicly owned		
Municipal electric utilities	897	1,052
Federal		
Bureau of reclamation	1	14
Other projects	4	32
Co-operatives, power districts, state projects, etc.	47	100
Noncentral stations	39	47
Subtotal	988	1,245

Production and installed capacity for 1940 within the nine geographic divisions reflected substantial increases over comparable figures for 1939. The 1940 report shows totals for each geographic division by months and the total number of plants and capacity at the end of the year. Comparative data on production, generating capacity, and number of plants by regions are shown in the following table:

		Total Production 1,000's of Kw-Hr	Number of Plants	Capacity (Kw)
New England	(1940)	8,968,302	353	3,067,641
	(1939)	8,350,362	357	3,028,280
Middle Atlantic	(1940)	36,383,373	412	9,878,243
	(1939)	32,969,952	419	9,746,991
East North Central	(1940)	33,612,066	700	9,489,020
	(1939)	29,995,003	699	9,069,488
West North Central	(1940)	8,481,207	876	3,316,710
	(1939)	7,859,695	867	3,157,538
South Atlantic	(1940)	17,617,508	426	5,171,478
	(1939)	15,190,108	434	4,843,202
East South Central	(1940)	8,471,576	187	2,144,322
	(1939)	6,967,949	208	2,001,627
West South Central	(1940)	7,433,502	439	2,104,851
	(1939)	6,979,694	431	2,041,071
Mountain	(1940)	8,544,075	405	2,217,379
	(1939)	7,492,621	402	2,156,800
Pacific	(1940)	15,472,956	311	4,253,312
	(1939)	14,530,666	309	4,272,927

Copies of the recently issued report may be obtained from the Federal Power Commission, Washington, D. C., at 25 cents each, remittance to accompany order. Stamps are not acceptable. For convenience in ordering, the report may be referred to as FPC S-13.

FPC Applies "Prudent Investment" Theory. Establishing a new basis for power rates, the Federal Power Commission has ordered Chicago District Electric Generating Corporation to reduce its rates to the Commonwealth Edison Company of Chicago by $521,978 annually through reducing the corporation's rate base to $34,355,469 and establishing its rate of return at 5½ per cent. Commonwealth Edison and Northern Indiana Public Service Company, supplying consumers in the Chicago and northern Indiana area, buy the entire output of the corporation's generating plant. The Commission's precedent-breaking decision applying the "prudent investment" theory as a basis for rate-making terminated a three-year investigation.

Von Siemens Dies in Berlin. Carl Friedrich von Siemens, German electrical industrialist, died July 10, 1941, at Berlin. He was 68 years of age. The son of Warner Siemens, founder of the Siemens concerns, Doctor Siemens entered the firm in 1899, and in 1902 was made manager of a branch of the London firm of Siemens Brothers and Company. In 1908 he returned to Berlin, and in 1912 became chairman of the board of directors of the Siemens Schuckert Works. He became chairman of the supervisory board of Siemens and Halske and Siemens and Schuckert in 1919, and it was under his directorship that the concern became one of the most important electrical undertakings in the world.

Charles Clark Robinson, superintendent of electric power plants for the Union Electric Company of Missouri, St. Louis, died July 18 at Sturgeon Bay, Wisconsin, following a paralytic stroke. Mr. Robinson was an electrical engineering graduate from the University of Missouri (1904). He was successively affiliated with the Telluride Power Company of Provo, Utah (1904–09); the Central Colorado Power Company, Denver (1909–12); the Union Electric Company (1912–41). Mr. Robinson was affiliated with the AIEE from August 25, 1905 until April 30, 1939.

F. E. Weymouth Dies. Frank Elwin Weymouth, general manager and chief engineer of the Metropolitan Water District of Southern California, Los Angeles, Calif., died July 22, 1941. Mr. Weymouth received the degrees of bachelor of civil engineering, 1896, and doctor of engineering, 1934, from the University of Maine. From 1899 to 1901 he was with the Isthmian Canal Commission, serving at various times in Nicaragua, Central America, and Washington, D. C. After a year as resident engineer with a South American railroad company, he became project engineer with the United States Reclamation service in 1902, supervising planning and construction on several large projects, and becoming chief engineer in 1920. He had been with the Metropolitan Water District of Southern California since 1929, first as chief engineer, and as general manager and chief engineer since 1932.

Other Societies

IES Formulates Revised Practice for Residence Lighting

A revised "Recommended Practice for the Illumination Performance of Residential Luminaires" has been formulated by the Illuminating Engineering Society, and adopted by the American Lighting Equipment Association. It is based on modifications and revisions agreed upon by the IES committee on residence lighting and the specifications committee of the ALEA. The revisions are intended to insure better lighting performance while allowing adequate latitude for decorative design of residential lighting fixtures. To a greater extent than has been heretofore attempted, the new "practice" classifies fixtures with respect to decoration and function, and lays down rules and principles governing their illumination characteristics.

NRC Committee Sponsors Electrical Insulation Symposium

A symposium on electrical insulation materials, sponsored by the National Research Council committee on chemistry, conference on electrical insulation, will be part of the program of the coming meeting of the

Future Meetings of Other Societies

American Association for the Advancement of Science. Convention, September 22–26, 1941, Chicago, Ill.

American Institute of Chemical Engineers. 34th annual meeting, November 3–5, 1941, Virginia Beach, Va.

American Society of Civil Engineers. Fall meeting, October 15–17, 1941, Chicago, Ill.

American Society of Mechanical Engineers. Fall meeting, October 12–15, 1941, Louisville, Ky.

Annual meeting, December 1–5, 1941, New York, N. Y.

American Welding Society. 22nd annual meeting, October 19–24, 1941, Philadelphia, Pa.

Association of Iron and Steel Engineers. Annual convention, September 23–26, 1941, Cleveland, O.

Illuminating Engineering Society. Annual convention, September 22–25, 1941, Atlanta, Ga.

National Metal Congress. October 20–22, 1941, Philadelphia Pa.

National Safety Council. 30th National Safety Congress and Exposition, October 6–10, 1941, Chicago, Ill.

Society of Automotive Engineers. National aircraft production meeting, October 30–November 1, 1941, Los Angeles, Calif.

National transportation and maintenance meeting, November 13, 14, 1941, Cleveland, O.

American Chemical Society at Atlantic City. The symposium will be held September 11, under the auspices of the division of industrial and engineering chemistry of the American Chemical Society. The program of the symposium is as follows:

INFLUENCE OF OXIDATION ON THE DIELECTRIC PROPERTIES OF HYDROCARBONS AND HYDROCARBON OILS. J. C. Balsbaugh, A. G. Ansaf, and J. L. Oncley, Massachusetts Institute of Technology

PAPER DIELECTRICS CONTAINING CHLORINATED IMPREGNANTS—DETERIORATION IN D-C FIELDS. D. A. McLean, L. Egerton, G. T. Kohman, and M. Brotherton, Bell Telephone Laboratories, Inc.

THE INFLUENCE OF REFINING TECHNIQUE ON ELECTRICAL STABILITY OF MINERAL OIL TREATED DIELECTRICS. F. M. Clark and E. L. Raab, General Electric Company, Pittsfield, Mass.

THEORY OF DIELECTRIC LOSS IN POLAR POLYMERS. John G. Kirkwood, Cornell University.

DEPENDENCE OF DIELECTRIC LOSS ON MOLECULAR WEIGHT IN THE SYSTEM OF POLYVINYL CHLORIDE-DIPHENYL. R. M. Fuoss, General Electric Company, Schenectady, N. Y.

RELATION OF DIELECTRIC PROPERTIES TO STRUCTURE OF LINEAR POLYAMIDES AND POLYESTERS. W. A. Yager and W. O. Baker, Bell Telephone Laboratories, Inc.

Wood Pole Standards Adopted by ASA. The American Standards Association has adopted formally as American Standards six tentative standards covering specifications for wood poles. The standards were prepared under the sponsorhsip of the ASA Telephone Group which is made up of the Bell Telephone System and the United States Independent Telephone Association. A consistent system of standards is fixed for the six major pole timbers of the United States, on the basis of tentative standards which have proved satisfactory through several years' trial use. Included in the standards are specifications for shape and straightness of grain, limits on departure from straightness, definition of minimum quality acceptable, and specifications for dimensions. Copies of the new edition of these standards may be ordered from the ASA Headquarters, 29 West 39th Street, New York, N. Y., at 20 cents each.

NEMA Revises Motor and Generator Standard. A revised standard covering motors and generators has been released by the National Electrical Manufacturers Association. The publication, No. 41-64, entitled "NEMA Motor and Generator Standards," supersedes publication No. 38-49 released in 1938. It contains all standards approved to date, and includes information as to standard dimensions, rating, and tests. Copies may be obtained from the National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y.; price $3.50 per copy.

Letters to the Editor • • •

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers: publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Total Security—A Challenge

To the Editor:

The address of Charles E. Wilson, president of the General Electric Company, published in the March issue of ELECTRICAL ENGINEERING, is most timely. His grave warning—that we must proceed promptly and on a realistic premise in the development of a program which will contribute to our "total security"—cannot be too strongly emphasized. His diagnosis—that the present world upheaval is a revolution of the masses who clamor for "more economic freedom and security"—is only too true. The masses sense correctly that "want in a new world of plenty" is unnatural and must be blamed on faulty leadership. His conclusion—that the present trends of corrective measures are in the wrong direction, as they all try to reach their goal of "more economic freedom and security" by curtailing "freedom" through growing government control—is also only too true. Mr. Wilson's firm belief in the free-enterprise system is fully justified. Its past 60 years performance and achievements are sufficient proof of its correctness.

In an intensive study of the "Social-Economic Problem" for the past 8 years on the novel basis of engineering research, the writer has arrived at the same general conclusions that Mr. Wilson expresses as to the nature of the present world upheaval and as to the need of finding a solution without destroying the free-enterprise system. As to the basic cause, effect, and consequential remedy, however, the writer's investigations lead to entirely different conclusions.

Without trying to argue any of Mr. Wilson's detailed suggestions, which in themselves might all prove helpful, the writer believes that these suggestions do not strike at the root of our trouble and therefore could not possibly bring the intended relief.

Mr. Wilson starts from the premise that our problem must be solved by economic means, because its cause is economic. This customarily assumed but tragically erroneous premise overlooks the fact that the problem confronting us is inseparably social-economic. The "power and machine age" with its abundance of machine forces has substituted permanently for a part of a nation's active man power and will do so at an ever greater rate.

This economic change has destroyed forever the past social equilibrium, in which, throughout the history of mankind, the whole manhood (*maximum* national man power) was required to perform a nation's work. Instead, the new condition is searching for a *new* social equilibrium, in which only a *minimum* of the national man power will be required for active service. The social effect under this new condition is a steady and unrelenting shift within the nation's manhood from active to superfluous (retired) manhood, with the whole of the manhood, however, remaining biologically responsible for the perpetuation of life, by mating and caring for its offspring.

While the cause of our new condition is thus economic, the effect must be considered as social, and accordingly the remedy to be applied must be social. Our present social-economic ills, including the present war, can thus be traced to one single basic cause—our mistaken attitude towards superfluous labor, by viewing such superfluous labor as a curse instead of recognizing it as the natural blessing of the new era.

The only solution for this new situation is to arrange for a freely and beneficially functioning shift from active to superfluous manhood by an adequate distribution scheme which will divide equitably the national produce among the whole manhood. This is possible by reorganizing a nation on the basis of a mutual retirement insurance, with income as basis and the income tax the premium on such retirement insurance. In actuality such income tax will be used to support the contemporary superfluous (retired) at their normal net existence level throughout their retirement in expectation that the same privilege be accorded to the contributor by the next generation, when he himself reaches the retirement age.

Mr. Wilson's suggestion that wise and courageous men from the ranks of free enterprise should get together is very valuable. But such get-together would be losing precious time if it were to continue to try to do the impossible of finding employment for the unemployed. Instead, the writer believes such get-together should concentrate on the verification of his contention that the problem is social; that its only solution is to provide for the complete and beneficial withdrawal of the superfluous man power from the labor market by means of a national retirement scheme; and that only such solution can restore the free functioning of the free-enterprise system and democracy itself.

Let large corporations with engineering research departments expand their work in this new direction by delegating philosophically inclined engineers to the most urgent task of "foundation engineering in the human-existence problem". The laws controlling this are just as rigid as those in the physical world. Though only qualitative analysis is feasible by such method, this limitation will not prove a handicap as it will be sufficient for such research to be able to indicate unmistakably the trend which our human actions will lead us to, that is, towards establishing heaven or hell on earth.

Mr. Wilson's clarion call augurs well! Total Security is possible! The free-enterprise system and a freely functioning democracy are essential if maximum freedom is to be assured as well. The technical machinery for this promising condition has been created by the achievements of the machine and power age, a living monument of the free-enterprise system.

Total security with maximum freedom is a challenge—a challenge which can be answered by the engineering profession! Shall we engineers meet it and help thereby save democracy from within? Or shall we ignore it and let ourselves be destroyed by the very machine we have helped to create?

The fate of modern civilization will be sealed by our answer and decision in this momentous question.

PAUL ACKERMAN (A'13)

(Consulting engineer, Montreal, Quebec, Canada)

Editor's Note: Mr. Ackerman suggests that his "help and advice are available to anyone desirous to undertake the verification and propagation of the discovered social-economic truth" to which he refers in this letter. Readers wishing more detailed information on Mr. Ackerman's plan should write directly to him. Mimeographed copies of the complete presentation may be obtained by sending postal note of $1.00 per copy (postage included) to the author at 4078 Hingston Avenue, N. D. G., Montreal, Que., Canada.

Facts Versus Propaganda

To the Editor:

"Facts Versus Propaganda," in ELECTRICAL ENGINEERING for August, pages 371–3, is one of perhaps a half-dozen articles on the general subject that have appeared in recent months. My thought for some years has been that the subject deserves much more attention than it has received in my lifetime.

My illustration for the method of teaching that Doctor Adams condemns is the building of a dump. Such a heap may be started at any time and any place, without preparation, plan, or foundation, and continued in the same way. Although the builder may collect a few social degrees while he is building, when he stops all he really has is another mental dump, plus the right to teach others to build the same way.

A comparatively short time ago, primitive man used to roast one of his fellow-primitives every spring, for insurance against famine. The more copious the tears of the roasted one, the more abundant the summer rainfall to come, and therefore the better the crops. This practice had the sanction of centuries, and primitive man was quite satisfied with his logical reasoning. What the victim thought did not count. He was so trussed up that all he could do was to roll from side to side above the fire, on the comfortable V-shaped broiler his considerate fellows had provided so that he might not die until after he had shed all his tears.

The logic and the torture were both flawless, despite the erroneous premise, so when a famine came the fault lay with the evil spirits who had led to the choice of a sacrifice deficient in his supply of tears. Because the sanction of centuries suffices for primitive minds, early primitive man persevered in his pleasant little pastime, and the annual crop of victims continued.

Today countless centuries of teaching by authority, instead of by experimentally determined fact and true reasoning, again are bearing fruit, just as through the ages. In the United States the pupils fall for Millers and Ponzis and other equally skillful spellbinders. In the "verboten" part of the world they fall for maniac Hitler. The fruits of the rubbish-dump method of teaching always have been vicious. Reason tells us that they always will be. Perhaps some day more of us will listen to reason. I hope Doctor Adams' article will have wide publicity.

H. H. KETCHAM (A'13, M'23)

(Editor, International Correspondence Schools, Scranton, Pa.)

Books for Engineers

To the Editor:

As electrical engineer in charge of a small power system, the writer wishes to open the question of books for professional men. Conditions are not what they should be from the standpoint of practical value to the purchasers of many volumes covering engineering subjects. My contention is that if books are to be marketed they should serve their purpose as engineering aids.

As an example in my own experience two texts come to mind: "Symmetrical Components" by Wagner and Evans and "Electric Circuits" by the Electrical Engineering Staff of Massachusetts Institute of Technology. Having obtained these excellent treatises and seemingly having progressed slightly in masticating their contents, a deep disappointment arose. Of the various questions and problems presented for perusal, no answers were published. Evidently these productions were intended primarily as texts for engineering students, hence the secrecy. Requests for copies of the answers only bring the reply that answers are not available to the general public. Of course an engineer does not class himself as "general public", but he may be such.

It is well known that a maintenance, construction, and operation program presents so many and such varied problems that engineers charged with these responsibilities cannot devote a great deal of time to design and abstract theory. This is why it was the wish of the writer to check some of the known factors and values on his system with the results obtained in the theoretical way. If he were expert enough to feel that the correct result has been obtained for each problem, no text would be desired and the book would not have been purchased. It is unfair and negligent to dispose of these books to engineers without making all of their advantages available. It is felt that in the examples mentioned only a fraction of the book value is obtained.

CLARK J. WELLS (M'37)

(Power superintendent, United States Department of Interior, Coolidge, Ariz.)

Conserved-Pressure Air-Blast Circuit Breaker

To the Editor:

I should like to enquire by what method the assigned rating of the breaker described in the paper by W. R. Rankin and H. M. Bennett (*AIEE Trans.*, '41 (*May*), *p. 193–7*) has been derived from the test results.

The test voltages given in table I of the paper (22, 44, 88 kv etc.) are presumably the nominal applied voltage in each case, and not the measured recovery voltage. Even if for the moment they are taken as recovery voltages (the real recovery voltage might of course be less) it seems difficult to justify the rating of 1,500 kva at 138 kv corresponding to a breaking capacity current of 6.3 ka.

Table A

Percentage of Rated Symmetrical Breaking Current	Minimum Recovery Voltage Required by B.S.S. 116–1937 Part 2 as Percentage of System Voltage for Rating 1,500 Kva	Actual Values of Test Current and Recovery Voltage Corresponding to Columns 1 and 2 Related to a Rating of 1,500 Mva 138 Kv		Results Obtained on Tests Taken From Table I of Paper	
		Ka	Kv*	Ka	Kv
(1)	(2)	(3)	(4)	(5)	(6)
10	95	0.63	114	1.61	132
30	95	1.89	114	1.61	132
60	60	3.8	72	3.6	88
100	30	6.3	36	4.4	44
				10.7	22

*These values are calculated by applying the percentages of column 2 to the equivalent single phase test voltages of $\frac{138 \times 1.5}{1.73} = 120$ kv.

Columns 1, 2, 3, and 4 of table A give the values of test voltage and current required by B.S.S. 116–1937, Part 2, to correspond to a rating of 1,500 mva at 138 kv. The nearest results actually obtained according to the paper are shown in columns 5 and 6.

The maximum rating that could be assigned to the breaker according to the British specification is thus:

$$\frac{4.4}{6.3} \times 1{,}500 = 1{,}050 \text{ mva at } 138 \text{ kv}$$

Alternatively, if the rating were based on the test at 10.7 ka, 22 kv the rated voltage would have to be reduced to

$$22 \times \frac{1.73}{1.5} \times \frac{100}{30} = 85 \text{ kv}$$

and the breaking capacity would become

$$10.7 \times 85 \times 1.73 = 1{,}570 \text{ mva}$$

C. C. GARRARD (A'06)

(Head of switch and transformer works, General Electric Company, Ltd., Witton, Birmingham, England)

"Student Section" for EE

To the Editor:

For a while I thought a moratorium had been declared on the topic "A Simple Method of Calculating Power Factor" but I see in the August issue of ELECTRICAL ENGINEERING that the discussion has started all over again. I'm not going to comment upon nor discuss this power-factor calculation (I had my say in the March 1941 issue), but I do want to comment upon the increased interest of student members toward ELECTRICAL ENGINEERING as shown by their numerous contributions to the "Letters to the Editor" page.

I feel that the student membership in the AIEE is sufficiently large and the student interest in ELECTRICAL ENGINEERING is sufficiently great to warrant a page or two in this magazine devoted entirely to student discussions, letters, papers, news of student activities, enrollment, and so forth. This would create increased activity among the Student Branches which would result in an increase in student membership in the AIEE.

The benefits the electrical-engineering student would derive from such a "Student Section" are many. First, he would develop the style and technique of technical writing and expression. Second, his comments and criticisms on engineering education might give the educators a better understanding of the electrical-engineering student and so in time help him in his school work. Third, news of the activities of the different Student Branches would cause a greater affinity between Branches.

The handling of material for this "Student Section" could be put into the hands of a small group of students and the Branch secretaries could be given the added duty of college representative—or better, give the Branch vice-president something to do. Let him be the college representative.

I petition you to look into the possibilities of having a few pages of ELECTRICAL ENGINEERING devoted exclusively to the writings and news of student members and Student Branches and ask you student members who might read this letter to send a similar petition to G. Ross Henninger, editor of ELECTRICAL ENGINEERING and offer suggestions and convincing arguments that would warrant the existence of a "Student Section" in ELECTRICAL ENGINEERING.

SANFORD HERSHFIELD (Enrolled Student)

Cooper Union Institute of Technology, New York, N. Y.)

Books Received •

"The Mechanism of the Electric Spark." In this analysis of the present status of the theory of the mechanism of the electric spark in air, L. B. Loeb and J. M. Meek develop a new streamer theory of spark discharge. A general unified theory applicable to various gaps and configurations of electrodes is set forth, from which the methods of computation given enable one to predict in advance the breakdown potential of any spark gap for direct current in the absence of space-charge distortion, and where field distribution in the gap can be calculated. Published by the Stanford University Press, Stanford University, Calif.; 173 pages; price $3.50 per copy.

"The Guntersville Project." This, the fourth in a series of technical reports from the Tennessee Valley Authority, describes the planning, design, and construction of the Guntersville Project on the Tennessee River. The first three reports, which have been reviewed previously are "The Norris Project", 1939 (*EE, Sept. '40, p. 396*), "The Wheeler Project", 1940 (*EE, June '41, p. 310*), and "The Pickwick Landing Project", 1941 (*EE, Aug. '41, p. 418*). As in the other reports, this volume outlines the preliminary social and economic investigations necessary for the project; the designing of locks, dams, and powerhouses; the planning of employee housing, and access roads; methods used in construction and in river diversion; reservoir activities; initial operations; and a summary of construction costs. Appendixes include a statistical summary of the physical features of the project, copies of reports of consulting engineers and geologists, and summaries of special tests. Copies of the 423-page, illustrated report may be obtained from the Treasurer's Office, Knoxville, Tenn., at $1.00 each.

"Results of Municipal Electric Systems." Seventh edition, 1941. This 428-page electric rate book based on reports as to the use and cost of electricity from 758 municipally owned light systems shows that more than half such systems have lowered rates since the 1939 edition of the book, and that a majority of the cities have no bonded indebtedness on their municipal systems. Contained in the book are operating records of earnings, output, rates, revenues, valuation, and also facts pertaining to the increasing use of electricity and the decreasing cost of electricity in municipal installations. Much of the latter information is given in graphs and tables. Copies may be obtained from Burns and McDonnell Engineering Company, Kansas City, Mo., at $5.00 per copy, prepaid.

"Technical Lettering." This book of directions for and exercises in technical lettering, by E. P. de Garmo and Finn Jonassen, aims at enabling the engineer or draftsman to present information clearly and concisely, with as rapid execution as possible. It contains minute instructions as to technique and methods of obtaining the best results. Materials for lettering, proper position of paper and drawing board, and the correct way to hold the drawing instrument are described. Space is provided for practice in lettering. Published by the Macmillan Company, New York, N. Y.; price $1.00.

"How Inventors Can Aid National Defense." This booklet issued by the National Inventors Council (see *EE, Nov. '40, p. 477*) of the United States Department of Commerce, contains information as to the purpose of the Council, the character of potentially useful inventions, and the defense value of inventions. The appendix gives biographical sketches of Council members, technical committees of the Council, suggested procedure for submitting inventions, and a list of literature. Copies of the 22-page report may be obtained from the United States Government Printing Office, Washington, D. C.

"Industrial Health Practices." This report presents a survey of 2,064 industrial establishments compiled by the committee on healthful working conditions of the National Association of Manufacturers, and conducted under the direction of Doctor Victor G. Heiser. It includes information as to the value of a factory health program, physical examination policies in the plants under consideration, representative features of a factory health program, and cost of health programs and length of time that these have been in existence, classified according to size of company and type of industry. Comparisons are made of present status and progress with that noted in earlier reports. Copies of the 76-page illustrated report are available to NAM members and nonprofit organizations at no cost, and to others at 50 cents each. They may be obtained from the National Association of Manufacturers, 14 West 49th Street, New York, N. Y.

"Hotel Engineering. Volume Two, Electric Current Consumption, Cost and Savings." This second book on hotel engineering problems published by the national membership division of the American Hotel Association, and prepared under the supervision of G. C. St. Laurent, contains information on many matters pertaining to electric current consumption, with suggestions as to cutting costs and making savings. Topics discussed in the book include: electric current rates, Diesel engines for hotels, guest room air-conditioning units, fluorescent lighting, electric and gas cooking, economy in lighting, savings on elevator operation, and central cleaning plant and small portable units. Copies may be obtained from the American Hotel Association of the United States and Canada, 221 West 57th Street, New York, at $1.50 per copy.

The following new books are among those recently received at the engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

MANUAL OF ENGINEERING DRAWING FOR STUDENTS AND DRAFTSMEN. By T. E. French. Sixth edition. Revised and enlarged. McGraw-Hill Book Company, New York and London, 1941. 622 pages, illustrated, 9½ by 6 inches, cloth, $3.00. New edition of a standard textbook considerably revised. Page size has been enlarged to allow an increase in the size and number of illustrations; many problems have been changed and added; and in addition to revision of existing chapters new ones have been included on aircraft drawing, jig and fixture drawing and welding drawing. Material conforms to the standards of the American Standards Association. Bibliography of allied subjects.

THE BOULDER CANYON PROJECT, HISTORICAL AND ECONOMIC ASPECTS. By P. L. Kleinsorge. Foreword by R. Jones. Stanford University Press, Stanford University, Calif., 1941. 330 pages, illustrated, 9½ by 6 inches, cloth, $3.50. The whole system of related works comprising the Boulder Canyon Project (not merely the Hoover Dam construction and its resulting reservoir area) is discussed. The history of the project is reviewed, and the economic significance of this flood control, irrigation, power, and water supply system is explained in detail. Geological and engineering aspects of the various dams, canals, and aqueducts are also considered.

AIR RAID PRECAUTIONS (in ten parts), reprinted by permission of the Controller of His Britannic Majesty's Stationery Office. First American edition. Chemical Publishing Company, Brooklyn, N. Y., 1941. Diagrams, etc., 9 by 5½ inches, cloth, $3.00. In the ten separately paged sections of this manual are brought together and amplified the materials published previously in the A.R.P. handbook and memorandum series. Topics discussed include the organization of the air raid wardens' service, communications systems, rescue parties, and clearance and decontamination work; structural defense and window protection; gas detection and identification; training procedures; and the inspection, care, and repair of equipment.

TRANSFORMERS. By E. E. Wild. Blackie and Son, London and Glasgow; Chemical Publishing Company, Brooklyn, N. Y., 1940. 132 pages, diagrams, etc., 9 by 6 inches, fabrikoid, $2.50. One of a series of small volumes dealing with particular sections of electrical engineering. A concise account of the theory, design and operation of transformer types, and a number of worked and unworked examples are presented.

Transactions Section

Preprint of Corresponding Pages From the Current Annual Transactions Volume

Any discussion of these papers will appear in the December 1941 "Supplement to Electrical Engineering—Transactions Section"

Bus Protection Independent of Current-Transformer Characteristics

G. STEEB
MEMBER AIEE

Synopsis: The paper describes the installation and operating results of a bus protective scheme, which uses a combination of high-speed directional ground relays on all sources of fault current and high-speed plunger type blocking relays on all outgoing circuits. The scheme described is independent of the ratios and characteristics of the current transformers.

Introduction

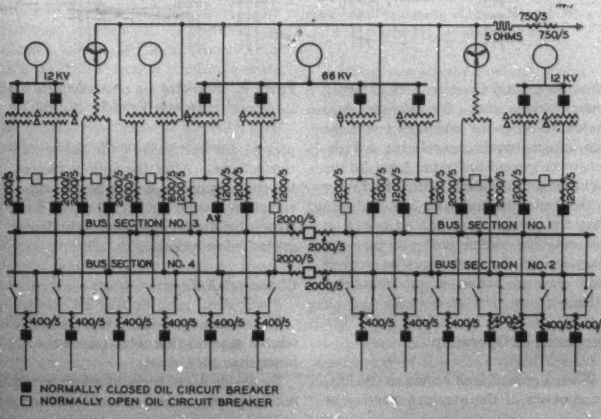
THE protection of station busses in the past has usually been accomplished by some form of differential relaying or by fault bus relaying.[1]

Differential relaying requires that the current transformers in each circuit on the bus have the same ratio and characteristic.[2] Sometimes auxiliary transformers are used to compensate for differences in the ratios of various current transformers.[3] It has often been necessary to give the differential relays a relatively high pickup and some time delay in order to prevent incorrect operations. The application of the harmonic current restraint relay has overcome some of the difficulties of differential relaying for bus protection.[4]

Fault bus relaying requires that all equipment be insulated from ground and connected to a common fault bus, which is grounded through a current transformer which operates some type of relay.[5]

Neither of the above schemes could be applied in a practical way to the bus layout shown in figure 1. Since each feeder has only one breaker, and each pair of feeders has selector disconnects to the busses, the application of current transformers for differential relay protection would not be feasible. This station is a 22-kv outdoor station which was built 20 years ago and does not lend itself readily to the application of the fault bus method.

Figure 1. Circuit arrangement of 25-cycle, 22-kv outdoor station



Description of Bus Scheme

The difficulties in applying either of the two conventional methods of bus protection resulted in the development of a scheme which uses a combination of high-speed directional relays on all sources of fault current and high-speed plunger type current relays for blocking on all outgoing circuits. The method developed can be used for protection against any type of fault, but, after consideration of the speed of operation of the protective scheme and of the fact that the majority of faults in an outdoor station start as one wire to ground or two wires to ground faults, it was decided to install only ground fault protection. The total relay time of the protective scheme is from one to two cycles* and it was felt that this time was sufficiently short to insure relay operation before ground faults have sufficient time to develop into three-phase faults.

Figure 2 shows the simplified a-c connections for bus sections 1 and 2. Figure 3 shows the schematic d-c relay connections for bus sections 1 and 2. The connections for bus sections 3 and 4 are similar to those shown for bus sections 1 and 2.

Each of the high-speed ground directional relays used on circuits which are sources of ground current has one coil connected in the station neutral ground and its other coil in the respective residual current circuit. When de-energized, the contacts of these relays are open, and they close when ground current flows toward the protected bus section. A specially designed *b* switch on the oil circuit breaker in each circuit is connected across the

Paper 41-99, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 1, 1941; made available for preprinting May 5, 1941.

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1. For all numbered references, see list at end of paper.

* All times given are on a 25-cycle basis.

normally open contacts of these relays to prevent the relay scheme from being inoperative when a circuit is out of service.

All circuits which are not sources of ground current are provided with high-speed plunger type ground relays, each having two contacts both of which are closed when the relay is de-energized. Since the outgoing circuits can be connected to either one of two busses, it was necessary to use one contact of each of these relays in the protective scheme of each of these bus sections. Thus the operation of these relays, when a fault occurs on a circuit off the bus, blocks the bus scheme of both bus sections to which the circuit can be connected. The contacts of these relays are continuously supervised by indicating lights.

The tie breakers to adjoining bus sections are equipped with both high-speed ground directional relays and high-speed plunger type ground relays with their contacts connected in parallel. Since an adjoining bus section may or may not be a source of ground current, it was necessary to install both types of relays. The normally closed contacts of the plunger type ground relays of the tie breakers also serve as *b* switches when the breakers are open. The tie breakers are normally open at least 90 per cent of the time.

To prevent an accidental operation of the bus scheme and also to prevent its operation on a high-resistance fault on a circuit off the bus, a high-speed plunger type overcurrent relay for each bus section is used in the station neutral ground. The contacts of this relay are connected in series with the operating coil of the gang trip relay, the normally open contacts of the ground directional relays, and the normally closed contacts of the plunger type ground relays for any bus section. Since the ground directional relays have a lower pickup than the plunger type ground relays on the outgoing circuits, the bus scheme would operate on a high-resistance ground fault were it not for the fact that the high-speed overcurrent relay in the station neutral has a higher pickup than the plunger type ground relays on the outgoing cables and prevents the operation of the bus relays on ground fault current below a predetermined value.

Sequence of Operation

When a ground fault occurs on the bus, the contacts of the overcurrent relay in the station neutral and of the ground directional relays in the circuits which are ground sources close, energizing the gang trip relay which trips all the power sources on the bus. Since the outgoing feeder circuits carry no fault current, the contacts of the relays on these circuits remain in the normally closed position.

When a ground fault occurs on a circuit off the bus, the contacts of the plunger type ground relay on the faulted circuit open before the contacts of the overcurrent relay in the station neutral and the ground directional relays close and thus prevent the operation of the bus protective scheme. After the fault is cleared, the contacts of the station neutral relay, and of the ground directional relays, must reopen before the contacts of the feeder ground relay reclose.

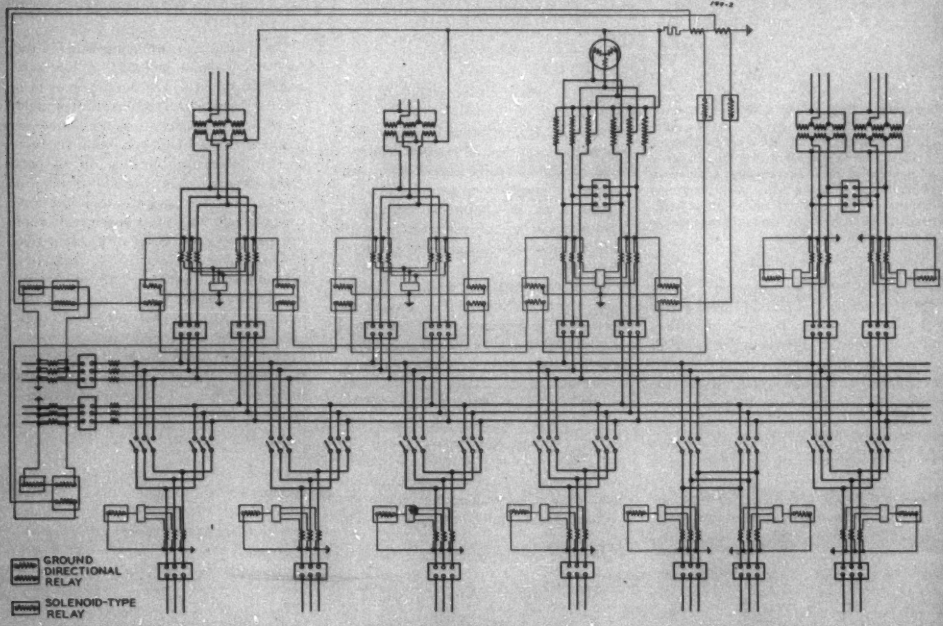

Figure 2. Simplified a-c connections for bus sections 1 and 2

Choice of Relays

The correct operation of this protective scheme requires that relay contacts open faster than they close.

To decide what types of relays would fulfill this requirement, a number of tests

were made in the laboratory, using an oscillograph, to check the relative opening and closing times of the various relays. It was found that satisfactory tolerance can be obtained between the opening of one contact and the closing of another, even on high-speed plunger type relays which are energized or de-energized simultaneously. The tests also showed that the contacts of five directional relays in series, operating simultaneously, give reliable results especially if the contacts are of the nonbounce type.

The relays that have been selected are all of simple design, and their operating times as recorded by the oscillograph, are described below.

The high-speed plunger type relays in the ungrounded circuits will open their contacts in a quarter of a cycle at all values of current greater than about 30 per cent above their setting, and after the current has been removed, the contacts will reset in one cycle. Of course the setting of these relays should be made as low as possible, because this determines the setting of the relays in the station neutral.

The high-speed plunger type overcurrent relays in the station neutral will close their contacts in a third of a cycle at the maximum obtainable current, which is 300 per cent of their setting. The closing time of the relay contacts increases, as the current decreases, i.e., at about 30 per cent above the setting the time will be one cycle and two cycles at 5 per cent above its setting. The contacts open in a quarter of a cycle after the relay becomes de-energized.

The high-speed ground directional relays have been adjusted to close their contacts in a time, varying from about two cycles at ten per cent above their setting to three-quarters of a cycle at the maximum obtainable current. These contacts will reopen in a quarter of a cycle after the relay becomes de-energized.

Additional tests showed that equally satisfactory results can be obtained with relays used on 60 cycles frequency.

Limitations of the Bus Scheme

1. If the unusual operating condition, should arise of a bus section being fed only through a tie breaker, it would be necessary to make the protective scheme nonautomatic on that section; since the *b* switches on every breaker that normally feed the bus section would be closed. The only contact that would then remain open in the d-c circuit of the bus scheme would be that of the overcurrent relay in the station neutral. Since these contacts close for a fault anywhere on the 22-kv system an incorrect operation of the bus protective scheme could result.

2. The bus protective scheme for a section would be inoperative if a breaker on a ground source circuit were in the closed position while its isolating disconnects were open. This is a situation that might arise while doing maintenance work on a breaker. If a bus ground fault should occur during this period, the ground directional relay on the circuit out of service could not close its contacts. This limitation of the bus scheme can be overcome by by-passing the *b* switch of the breaker on which maintenance work is being done.

3. The bus scheme of any section is inoperative while any of its relays is being tested. This, of course, applies to any bus scheme but with this one there are a greater number of relays to be tested than on a conventional scheme, and therefore more time is required.

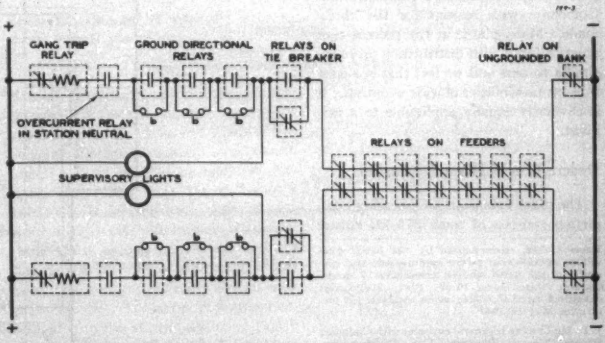

Figure 3. Schematic diagram of d-c relay connections for bus sections 1 and 2

4. This bus scheme does not operate if a bus fault starts as a phase-to-phase or three-phase fault or if a one wire-to-ground or two wire-to-ground bus fault changes to a three-phase fault in less than about one cycle after its start.

Staged Ground-Fault Tests

The various relays of the described bus scheme were installed and put in service in May 1939, but the trip circuits on the gang trip relays were left open temporarily. The purpose of this precaution was to determine, in actual operation, whether any of the relays would operate incorrectly on switching surges or external faults. During this period various disturbances occurred outside the four bus sections during which all the relays of the bus protective scheme performed correctly.

On May 12, 1940 a series of staged ground fault tests were made on each of the four bus sections and on circuits off the various bus sections. In each case the protective scheme operated correctly. Each of the bus faults was cleared in about seven cycles.

Operating Experience

Since May 12, 1940 when the bus scheme was put in service, there have been nine faults on circuits off the bus, and one fault on bus section 4.

The bus scheme was blocked correctly in all cases of faults off the bus.

The fault on the bus, which occurred on the bus side of the breaker bushings marked with the letter *A* in figure 1, was cleared in eight cycles through the operation of the bus protective scheme.

The record of the automatic oscillograph indicates that the disturbance started as a phase 3-to-ground fault. This condition remained for four cycles and after that the fault spread into a two wire-to-ground fault, involving phases 2 and 3.

Conclusion

The bus protective scheme has been applied to an important and rather complicated section of the system, where relatively large generators and power transformers are connected to the busses. Operating experience indicates that the reliability of this bus scheme is not adversely affected by either the magnetizing inrush currents of the power transformers or by the d-c component of the asymmetrical fault currents.

A Distribution System for War-Time Plant Expansion

J. L. McKEEVER
ASSOCIATE AIEE

Introduction

INDUSTRIAL distribution systems to meet the needs of expanding plant facilities for war and defense production are a very live issue today, both in Canada and in the United States. A great deal has already been written on the subject in a general way, as a guide to the proper tailoring of plant distribution to the type of plant and plant production. The purpose of this paper is not to generalize, but to offer a short description of the distribution system installed in the recently expanded facilities of the Peterborough plant of the Canadian General Electric Company, with reasons for the choice made. Many plants at the present time must be faced with distribution problems similar to ours and we feel that our solution has possibilities of wide adoption. It is obviously equally applicable to a new plant.

Description of Plant Extension

The plant extension now nearing completion consists of some 370,000 square feet of floor space in two single story buildings. One building of some 245,000 square feet was constructed to manufacture specialized mechanical equipment while the second building of 125,000 square feet area is to house our wire and cable manufacturing department. They will be designated in this paper as building *A* and building *B* respectively.

The types of load in the two buildings are quite different. In building *A* there will be a connected load of approximately 6,000 hp consisting very largely of small machine tools, plus 900 kva for heating and lighting, while in building *B* with a connected load of approximately 2,500 hp there are an appreciable number of motors in the order of 50 to 200 hp driving rubber mills, Banburys, strainers, etc.

Existing Distribution System

In laying out a distribution system for the new buildings the first thought naturally was to continue with the present system. Power is obtained from four sources, i.e.

Two small hydroelectric stations owned by the company

One steam turbine generator in the company's steam heating plant

Peterborough Utilities Commission

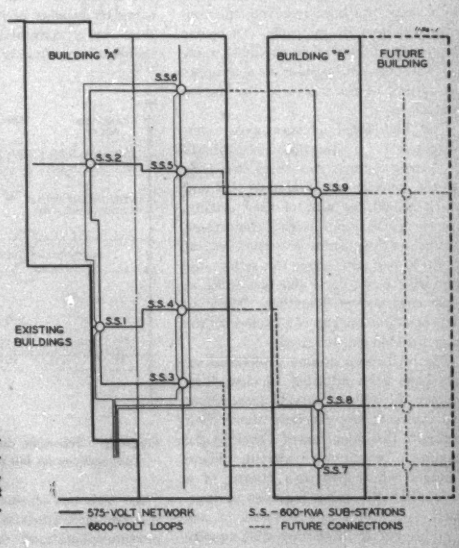

Figure 1. Approximate location of sub-stations in buildings, showing 6,600-volt and 575-volt interconnections

Paper 41-136, recommended by the AIEE committee on industrial power applications, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 16, 1941; made available for preprinting May 15, 1941.

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Grateful acknowledgement is made of the help given in the preparation of this paper by G. F. Langley, chief engineer, and F. A. Athney, switchgear engineering department, Canadian General Electric Company, Peterborough Works.

1. For all numbered references, see list at end of paper.

While the installation requires a greater number of relays than conventional schemes, it avoids the use of additional current transformers and is independent of the current transformer ratios and characteristics, and can therefore be more readily applied to old stations. Economically it compares very favorably with other schemes.

The protective scheme as installed is practically foolproof. Mistakes made while working on the individual relays or on the various current circuits are not likely to operate the bus scheme. Troubles in the secondary wiring or the relays are more likely to prevent the scheme from operating than to cause an incorrect operation, a condition which is desirable from a system operating standpoint.

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These sources are paralleled in the switch room of the steam plant and from there power is fed by 6,600-volt underground cables to four strategically located step-down substations. From these stations the existing plant of 790,000 square feet floor area is fed by conventional radial feeders at 575 volts for power and 115/230 volts for lighting.

Distribution Requirements

If the same radial type of distribution were to be used for the new buildings it was obvious that at least two new substations would be required and, considering the large area to be covered, it would be necessary to decentralize the 115/230-volt lighting transformer capacity by placing a number of small single phase units, either Pyranol or air cooled, throughout the buildings. This is of course in line with the best modern practice and the primaries could readily be connected to the 575-volt radial power distribution system, but there were other more serious problems to be solved.

While the load in building *B* both as regards amount and location was fairly well fixed before construction started, the situation with regard to building *A* was quite different. Here, for a variety of reasons, the final total of connected load could not be estimated at all closely and the layout was undergoing continual changes. Furthermore, due to the fact that the work for which this building was being erected was of a temporary nature, the distribution had to be laid out so that the building could be converted readily to a quite different type of manufacturing. In addition all concerned were interested in keeping costs to a minimum consistent with the conditions to be met.

Proposal

Mr. G. R. Langley, the chief engineer of the Peterborough Works, proposed the use of a number of unit substations with the primaries of the transformers connected into a 6,600-volt loop or ring main, and with the 575-volt secondaries interconnected to form a network. The lighting also was to be decentralized with the lighting transformer primaries supplied from the network. This scheme was adopted as a cost analysis showed that it would reduce the first cost and offer other advantages. While the idea of using a low voltage network for industrial distribution is not new, we believe that the scheme proposed has novelty in the use of the primary loop combined with a secondary network with simplified protection.

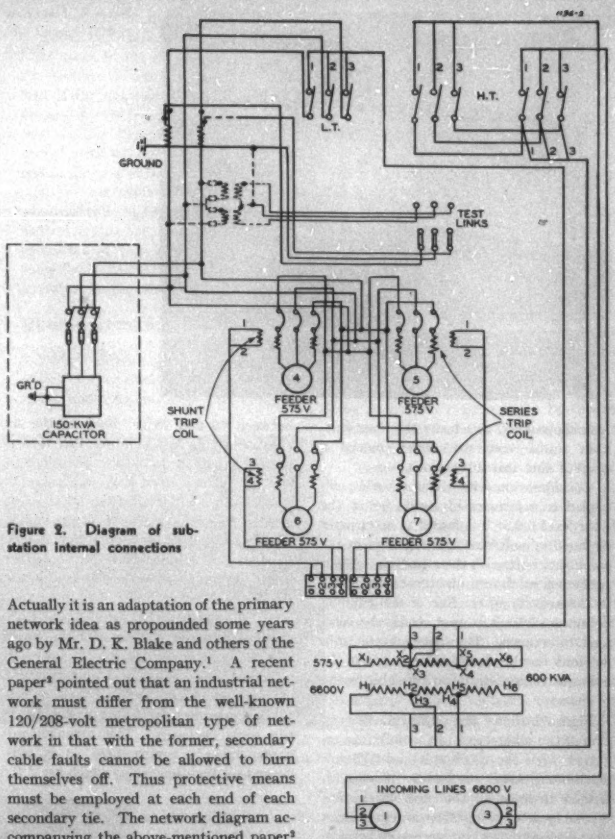

Figure 2. Diagram of substation internal connections

Actually it is an adaptation of the primary network idea as propounded some years ago by Mr. D. K. Blake and others of the General Electric Company.[1] A recent paper[2] pointed out that an industrial network must differ from the well-known 120/208-volt metropolitan type of network in that with the former, secondary cable faults cannot be allowed to burn themselves off. Thus protective means must be employed at each end of each secondary tie. The network diagram accompanying the above-mentioned paper[2] showed the network ties used simply as ties and protected by fuses or current limiters. The power feeders were taken off busses through air circuit breakers and network protectors were used between the busses and the transformers. Our system is admittedly not designed for uninterrupted service due to tie faults and simplifications were made in using the ties themselves as busses protected at each end by air circuit breakers and omitting the network protectors. So far as we are aware no similar system is at present in use in Canada or in the United States.

Evolution of Distribution System

Enquiries among other plants and at one plant in particular which had about the same type of load and approximately the same proportion of lighting, electric heating, and power load as we anticipated in building *A*, showed that we might expect a load factor of close to 50% and a power factor of between 70 and 75%. With a radial distribution system, allowance for growth and spare capacity would have necessitated the installation of about 4,500 kva in transformers for building *A* and between 2,000 and 2,500 kva for building *B*. With the network and loop system however, the ease with which a future additional substation can be connected into the system, together with its load dividing properties enables a considerable saving in transformer capacity. Incidentally this feature dispenses with one of the bug-bears of consulting engineers, namely the difficulty in drawing a mean between risk and over-conservatism in deciding upon transformer capacity. The capacity decided upon in our particular case was 3,600 kva for building *A* and 1,800 kva for building *B*. Investiga-

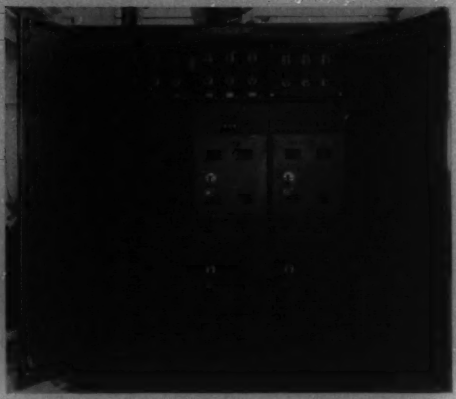

Figure 3. Front view of 600-kva unit substation

tion showed 600 kva to be the most suitable transformer size which meant a total of nine unit substations.

Consideration was given to using oil-cooled transformers in vaults below the floor level but it was found to be cheaper to use Pyranol filled transformers in the same enclosure with the switching. Floor space has minimum manufacturing value in the area along the line of the building columns where it cannot readily be serviced by cranes. Thus placing the substations on the floor backed against the columns represents no appreciable waste of space.

Figure 1 shows the approximate location of the substations in the buildings together with the 6,600-volt and 575-volt interconnections. Originally it was intended to have all the nine substations on one loop but a separate power contract for building *A* made it necessary to have two loops. This works out quite well however, as the wire building loop allows for the addition of three more substations in a future building alongside it so that actually the 6,600-volt cables for the two loops are identical.

The 575-volt switching in each station consists of four 400-ampere air circuit breakers of the dead-front type mounted two high as shown in figure 3. A low tension hook-operated disconnecting switch is provided for disconnecting the transformer from the air breakers, as shown on the top right of figure 3, while the two disconnecting switches appearing at the top left and centre permit the isolation of any section of the loop cable and also serve to disconnect the high voltage side of the transformer from the two ends of the loop.

It was mentioned earlier that the power factor to be expected in building *A* was between 70 and 75%. Each of the six substations in this building therefore is provided with a 150-kva capacitor controlled by the dead-front quick-break, fused knife switch showing at the left centre of figure 3. This is all the equipment provided in the substation except for one current transformer and some test links. Figure 2 shows the connections for the complete substation. The three substations in building *B* are identical with those in building *A* except for the omission of the capacitors.

Various designs of substation structure were considered and the final decision was to enclose transformer and switching in the same enclosure. This arrangement tends towards compactness as is evidenced by the dimensions which are 7 ft. 8 in. width, 8 ft. 6 in. depth, and 8 ft. 4 in. height. All wiring in the building for the 6,600-volt loop and the 575-volt network is overhead and the conduits are brought down the building column and through the roof of the substation.

Figure 1 shows the 575-volt interconnections between staticns and the various stub feeders. From junction boxes, taps are taken to 50-kva single-phase Pyranol filled lighting transformers and to GE Trumbull Swing-Wa power panels. In one case in building *B* where a number of controls for large motors are placed in an enclosed force-ventilated control room, two runs of Trumbull Flex-a-power are used between the substations these runs passing through the control room, and connections for the controls are made to them.

Protection

Considerable study was given to the protection of this distribution system against faults in any part of it. Experience with our present system has shown that faults are extremely rare in the 6,600-volt cables and transformers, and this in conjunction with the fact that the rare short interruption of power is not particularly serious with the type of manufacturing involved, permitted simplified protection. The oil circuit breakers at either end of each loop are equipped with inverse-time induction type relays with instantaneous attachments. The loop cables are large enough to feed all stations on the loop from one end, and as already mentioned, disconnecting switches are

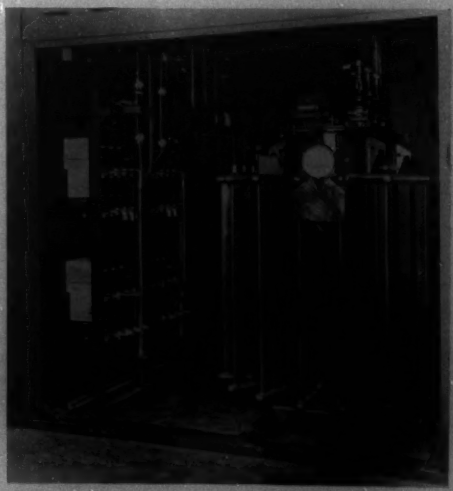

Figure 4. Internal view of 600-kva unit substation showing transformer, capacitor rack, and air circuit breakers

provided at each station so that any section of cable may be isolated. A temperature detector in the transformer winding will ring an alarm upon any serious temperature rise and should it become necessary to remove a transformer for examination or repair before a major fault develops, it can be removed from service without dropping load except on the stub feeders, by the following routine:

1. Trip the four 575-volt air circuit breakers to remove load from the transformer.
2. Open the loop disconnecting switches.
3. Open the 575-volt disconnecting switch and disconnect the transformer high tension leads.
4. Reclose the loop disconnecting switches and the four air circuit breakers.

An actual fault on either transformer or loop cable will open the loop oil circuit breakers and interrupt power for a short period but, as already mentioned, the inconvenience of such a shut-down does not, under our conditions, justify guarding against it.

The air circuit breakers in the network are provided with combination inverse-time and instantaneous overload trips which will give adequate selective protection. Calculations of fault currents have been made which indicate the maximum short-circuit current from all six stations at the terminals of any one of the air circuit breakers to be within safe limits. They also show the possible currents at the load side of the Swing-Wa power panels to be within the known tested rating of the standard cartridge fuses used. Actually the calculated fault currents are sufficiently low to allow considerable expansion beyond the six stations and indicate the feasibility of networks of larger capacity with the same standardized design of unit substation.

To provide peak load control, which may or may not be generally required, the network air circuit breakers are provided with shunt trips and a multi-conductor control cable is run from the operating room in the steam plant, allowing the operator to dump any section of the load if the contracted ten minute peak demand is liable to be exceeded. The stub feeders can obviously be disconnected without disturbing the network and in the case of the wire building where mention was made of two 575-volt network ties running through the large motor control room, one of these can be disconnected at each end dumping half the rubber mills but leaving the other half in operation on the other tie.

Direct-Current Supply

Direct current power is usually required for operation of cranes, boring mills, and certain other machines. In our case this power is supplied by motor-generator sets the induction driving motors of which are supplied from the network. With the load dividing feature of the network system such motor-generator sets can be connected into any convenient point close to the machines to be supplied without the prior thought necessary with radial feeders.

Figure 5. General view showing small space occupied by 600-kva unit substation

Comparison of Costs

In making a cost comparison between the network system described above and the radial system we would otherwise have installed we were fortunate in having access to the actual cost of a radial system recently installed in an Ontario plant of floor plan and area similar to building *A* in our plant. With the radial system the transformer capacity for building *A* alone would have been at least 4,500 kva and the costs from the other plant have been adjusted to this capacity. On this basis the network system showed a saving of 18½%.

With the present radial system in our plant it has been the practice to use reduced voltage starters on all squirrel-cage induction motors of 50 hp and larger. The excellent voltage regulation characteristics of the network system, however, made reduced voltage starters unnecessary and the omission of these brought the saving with the network system to 22½%, representing a figure in excess of $22,000 for building *A* alone.

Conclusion

The saving in capital expenditure realized by the use of the network system just described is sufficiently attractive in itself, but when this saving is coupled to the many other advantages the system offers, there seems to be good reason to expect its wide adoption.

Many plants in these days are faced with expansion problems similar to ours and it is hoped that our experience may be of value to others. The flexibility of the network system for increasing loads was impressed upon us recently by difficulties encountered with one of our existing radial substations in which the power transformer bank was seriously over-loaded. This substation had been built to take care of what at the time was thought to be ample future growth but it is now inadequate both in installed capacity and space for extension. In order to relieve the overloaded transformer bank it was necessary to split the 575-volt bus and feed part of it from a small transformer bank of incorrect characteristics for paralleling located in the test department substation several hundred feet away. Had we had a system similar to the one in our new buildings it would have been an easy matter to build another unit station and to connect it into the 6,600-volt loop and the 575-volt network.

The saving in transformer capacity, the saving in reduced voltage starters due to the good regulation, the high salvage value of equipment, and the simplicity of protection with the low-tension network and high-tension loop system of distribution have already been mentioned. These merits should assure its wide adoption in industrial plants.

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An Improved Frequency Meter for Commercial Power Frequencies

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MEMBER AIEE

Synopsis: While frequency meters of prior type admirably serve the purpose for which they are intended, their construction has been such as to necessitate the use of an external reactor. This external reactor is in most cases not objectionable, but for certain applications, where space is at a premium, a self-contained instrument is preferable.

This paper describes a frequency meter in which the external reactor has been eliminated by using an iron-core cross-coil instrument, the iron core serving the purpose of the normally external inductance, at the same time shortening the high reluctance air gap necessary for the moving coils.

Introduction

USING an iron core greatly reduces the ampere turns necessary to establish an adequate field intensity, which is proved by the fact, that while the power necessary to operate frequency meters

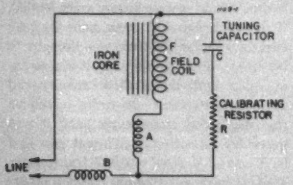

Figure 1. Schematic diagram of frequency meter

now being used range from 2.5 to 7.5 watts, depending on the design, this instrument consumes a maximum of 0.8 watt at 115 volts, or one-third the power of the prior instrument using the lowest power.

While the power consumption in most cases is insignificant with respect to the loss, it is important that a self-contained instrument use no more power than can be readily dissipated within the confinement of the case. Low power loss also simplifies compensation, as there is little change in temperature from the moment the instrument is energized till the temperature of the coils have reached constancy. In a self-contained instrument compensation is further simplified, because all components are mounted within the same container and therefore exposed to the same ambient temperatures, while if an external reactor is used, means must be provided to compensate for a possible difference of the temperature of the instrument proper and that of the reactor.

Theory

Referring to figure 1, the moving coil *A* is connected in series with the field coils *F* and therefore tends strongly to align itself with the magnetic flux in the air gap, the current through the coil being in phase with the flux. The capacitor *C* in series with the compensating resistor *R*, causes the resultant current in moving coil *B* to be 90 degrees out of phase with the air gap flux at the frequency corresponding to the center point of the scale. As the frequency varies from the center scale value, the power factor of the current in coil *B* will change, due to the altered impedance ratio between the field coils and the capacitor, resulting in a clockwise or counterclockwise deflection of the pointer, as the frequency increases or decreases.

As the power factor of the field coils, in series with coil *A*, is approximately 25 per cent, and the power factor of the current through coil *B* is about 97 per cent, four times as many turns, of correspondingly smaller size, may be used in coil *B* than in coil *A* for an equal heat loss in the two moving coils, resulting in a high order of deflection for a small change in power factor of the current in coil *B*.

The iron core is made from laminated "47-50" nickel iron due to its high resistance to corrosion and ease of stamping. Damping is provided by an aluminum vane moving through a strong unidirectional magnetic field established by an Alnico magnet.

Comments on Accuracy

The primary function of a frequency meter is, as the name implies, to indicate the frequency of an a-c circuit. Many causes tend to give an indication differing from the actual frequency, the most important of these are: Fluctuation of the line voltage, ambient temperature changes, and distortion of the voltage wave of the circuit.

Compensation for voltage influence has been accomplished by a high ratio of torque caused by the current flowing through the moving coils, to the torque of the ligaments connecting the moving coils to the stationary circuits. Figure 2 is a graph showing the voltage errors from 90 to 140 volts.

While conducting tests for voltage error on a number of instruments, some instruments would indicate erratically when high voltage was applied at certain frequencies. It was found that the two ligaments at one end of the moving coil assembly would short-circuit due to vibration of one of the ligaments, the vibration being set up by interaction between the magnetic flux in the air gap and the current through the ligament. The difficulty was overcome by cutting a turn of the ligament, thereby increasing its natural vibratory frequency above the measuring range of the instrument.

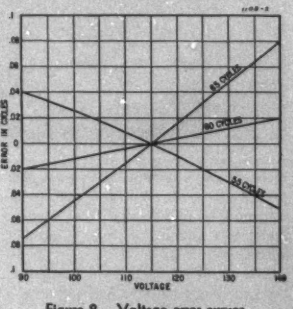

Figure 2. Voltage error curves

There are two main reasons for errors due to ambient temperature changes, they are: Resistance changes of coils and capacity changes of the capacitor used for tuning the field. In order to offset these errors, which have to be compensated simultaneously, a high temperature coefficient resistor is connected in series with the capacitor, thereby maintaining a constant phase relation between the current in the deflecting coil *B* (figure 1) and the magnetic flux in the air gap for a given frequency, at varying ambient temperatures.

It is important that a high-grade capacitor be used for an instrument, the purpose of which is to indicate small changes of reactance due to frequency changes.

Paper 41-108, recommended by the AIEE committee on instruments and measurements, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16-20, 1941. Manuscript submitted August 23, 1940; made available for preprinting May 5, 1941.

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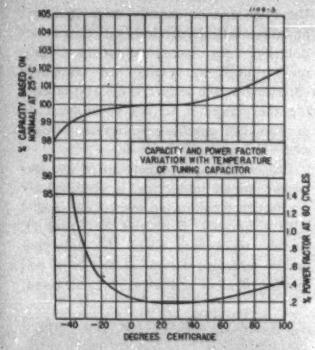
% CAPACITY BASED ON NORMAL AT 25° C
CAPACITY AND POWER FACTOR VARIATION WITH TEMPERATURE OF TUNING CAPACITOR
% POWER FACTOR AT 60 CYCLES
DEGREES CENTIGRADE

Figure 3. Capacitor-temperature capacity and temperature-power-factor curves

If considerable change of capacity would be caused by normal changes in ambient temperature, the instrument would be worthless as a frequency indicator; for this reason an oil-filled capacitor has been used, which has low and almost uniform temperature coefficient of capacitance within the normal range of temperatures. Figure 3 shows the capacity-temperature curve of the capacitor, and in addition the power factor-temperature curve. It will be noted that the power factor is almost constant within the measuring range, thus aiding the stability of the circuit.

As the temperature coefficient of capacitance is positive, it partly offsets the tendency of the instrument to read high at high temperatures, due to the increased resistance of the copper coils in the field circuit. Satisfactory compensation can be obtained between minus 20 and plus 45 degrees centigrade, by using a resistor in series with the capacitor, the temperature coefficient of the resistor having been adjusted to offset the combined causes tending to give an erroneous reading due to changes in temperature. Figure 4 shows the temperature error before and after compensation. While the capacitor has been under observation for a year, no change of capacity due to aging has been detected; it is however felt that insufficient time has passed to give exact data on aging characteristics.

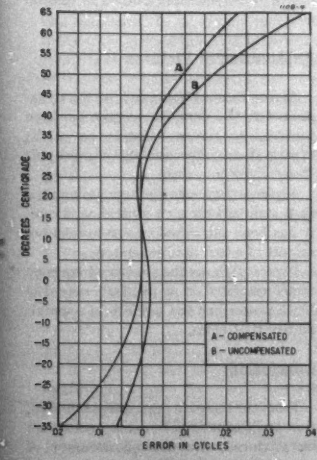

Figure 4. Temperature error of frequency meter

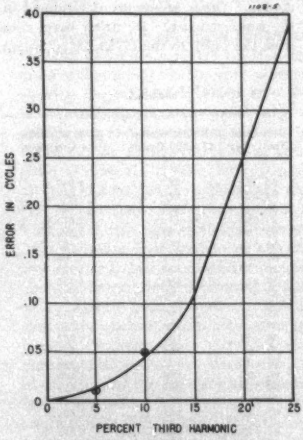

Figure 5. Third harmonic error

As the inductive reactance of the field circuit increases proportional to the frequency, and as the deflection of the pointer is caused by interaction between the moving coils and the magnetic flux of the field circuit, it will be seen, that the lower the harmonic present in the voltage wave, the greater is the tendency to indicate erroneously. Tests have been conducted to determine the effect of the third harmonic on the accuracy of the instrument, because this harmonic is the lowest commonly encountered in commercial supply lines. Figure 5 shows the error caused by varying magnitudes of third harmonic; changing the phase relation between the fundamental frequency and the third harmonic through 120 electrical degrees had no appreciable influence on the error indicated.

While the third harmonic influence seems rather high, it should be realized that the third harmonic, which is generally introduced into the voltage wave by the excitation of iron-core equipment due to the increased current at high saturation, seldom exceeds five per cent.

A four per cent seventeenth harmonic tooth ripple, present in the voltage of the generator used for calibration, had no influence on the accuracy, the indication being the same after eliminating the ripple by means of tuned by-pass filters.

Calibration

In order to obtain accurate calibration of the instrument without waste of time a multivibrator was used, having steps of 87,480, 29,160, 9,720, 1,620, 540, 180, and 60 cycles. The multivibrator is crystal controlled to one cycle in five million, its accuracy ascertained by comparing the time indicated by a synchronous electric clock, connected to the 60-cycles output stage, with radio time signals.

While the method of determining one frequency by its harmonic relation to another is not new, it is felt that it has been limited to a ratio, where it was possible to count the loops on the screen of the oscillograph. In the case where the harmonic ratio is more than 150 to one, counting the loops would be impossible without auxiliary means; a detailed description is therefore given of the method of calibration.

The instrument is calibrated by connecting the horizontal sweep circuit of an oscillograph to the 9,720-cycles stage of the multivibrator, and the vertical sweep to the variable speed generator used for calibration, the vertical sweep being amplified to extend beyond the limit of the screen, so as to show only two or three loops of the horizontal sweep, as indicated in figure 6.

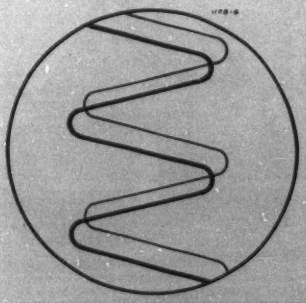

Figure 6. Harmonic oscillograph sweeps

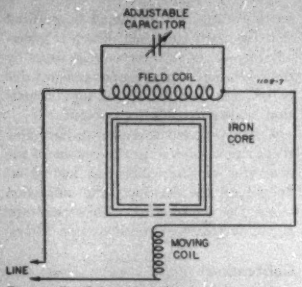

Figure 7. Schematic diagram of auxiliary frequency meter

As the frequency of the multivibrator is the 162nd harmonic of 60 cycles, some means must be employed to determine that the proper harmonic is used, there being only four-tenths cycle approximately between harmonics as compared to 60 cycles. A high-resistance voltmeter is connected in series with the 60-cycles stage of the multivibrator and the variable speed generator. The generator is adjusted until a steady reading equal to the sum of the voltages of the two supplies is obtained on the voltmeter. This reading is only obtainable when the voltages are synchronous and 180 degrees out of phase, the harmonic indicated on the screen must therefore be the 162nd.

In order to keep track of the harmonics used for calibrating the scale, an auxiliary frequency meter is used. The basic circuit of this instrument, shown in figure 7, is the same as that of the instrument under test, except that the restoring torque is provided by springs; the instrument is therefore accurate at only one point of the scale, the deflection at other points being dependent on the line voltage. An adjustable capacitor is used for adjusting the auxiliary instrument to center scale when the proper harmonic is found, by means of the voltmeter, at 60 cycles. As the sensitivity of the instrument is in the order of one-tenth cycle for full-scale deflection, it will be completely off scale if a wrong harmonic is used for calibration, and exact adjustment to center scale is therefore not necessary.

After the auxiliary instrument has been calibrated to 60 cycles, the setting of the adjustable capacitor is recorded and the speed of the generator is then slowly changed until the next harmonic appears on the screen. The auxiliary indicator again adjusted to center scale and the setting of the adjustable condenser recorded. Other points are determined in the same manner. By using harmonics from the 149th to the 177th, 29 points on the scale can be exactly calibrated and actual scale divisions determined by interpolation. Any harmonic can be readily redetermined by setting the adjustable capacitor to the proper value and adjusting the generator to the harmonic that permits the auxiliary indicator to read near the center of the scale.

Proper full-scale deflection of the frequency meter under test is obtained by connecting a calibrated resistor in parallel with either coil *B* or coil *A* (figure 1), thereby weakening either the deflecting or the restoring torque of the cross-coil moving element as the case may demand.

Table I

Generator Frequency	Subharmonic of 9,720 Cycles	RPM of Four-Pole Generator
54.915	177	1,647.5
55.227	176	1,658.8
55.543	175	1,666.3
55.863	174	1,675.9
56.185	173	1,685.5
56.512	172	1,695.3
56.847	171	1,705.3
57.176	170	1,715.3
57.515	169	1,725.4
57.857	168	1,735.7
58.207	167	1,746.1
58.552	166	1,756.6
58.909	165	1,767.3
59.268	164	1,778.0
59.632	163	1,788.9
60.000	162	1,800.0
60.373	161	1,811.2
60.750	160	1,822.5
61.132	159	1,834.0
61.519	158	1,845.6
61.911	157	1,857.3
62.308	156	1,869.2
62.710	155	1,881.3
63.117	154	1,893.5
63.530	153	1,905.9
63.947	152	1,918.4
64.371	151	1,931.1
64.800	150	1,944.0
65.233	149	1,957.0

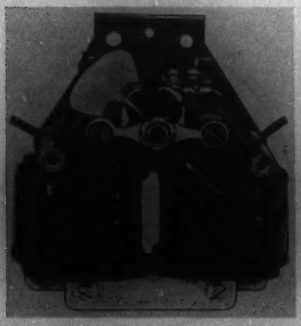

Figure 8. Frequency meter dynamometer

Figure 9. Frequency meter in six-inch case

Figure 10. Auxiliary frequency meter in five-inch case

Table I shows the frequency and speed in revolutions per minute of a four-pole generator corresponding to the harmonics being used for calibration, it is included for the convenience of those, who may desire to use the same method of calibration.

Explanation of Pictures

Figure 8 is a photograph of the dynamometer; the damping magnet has been removed to give a better view of the cross-coil assembly and the parallel pole faces of the iron core.

Figure 9 shows the instrument mounted in a standard six-inch switchboard case, it has been calibrated in revolutions per minute of a four-pole generator.

Figure 10 shows the auxiliary frequency meter mounted in a five-inch case, the black center line has a width of approximately 0.01 cycle.

Conclusion

From the foregone description it is seen, that a self-contained frequency meter can be produced, the over-all accuracy of which is better than two-tenths cycle in 60 cycles, permitting a third harmonic

Mechanical Simplicity of Air-Blast Circuit Breakers

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THE papers heretofore presented before the Institute on the subject of air blast circuit breakers have covered primarily their advantages in comparison with oil circuit breakers, the principles involved in current interruption by air blast, descriptions of interrupters developed by several manufacturing companies, the results of tests and related data. It is considered opportune to give an account of several other types of air blast circuit breakers ranging in voltage from 4 kv to 230 kv as developed and built by certain manufacturing companies in Canada and the United States in collaboration w th a large power company. The first machine of this general type was a 138-kv air blast breaker placed in service in 1934 at the Beauharnois generating station on lines to Montreal, this breaker having continued in service for six years successfully interrupting all faults; three additional breakers of the same general design with improved details have been placed in service at this station in later years.

Breakers of four types built by three manufacturing companies, all breakers having certain general features in common, will be illustrated by photographs and diagrams. In all of the breakers described, the general design of interrupting contacts is the same. This arrangement of contacts is suitable for the use of arc chutes utilizing any one of the elementary principles of pneumatic arc extinction or combinations of such principles.

Types marked "A" include breakers for 138 kv and 230 kv built by the English Electric Company of Canada.

Types marked "D" are 69-kv breakers built by the same company.

Types marked "B" are breakers of 15 kv to 37 kv built by the I-T-E Circuit Breaker Company, in Philadelphia.

Types marked "C" are breakers of 4 kv to 15 kv built by the Eastern Power Devices Limited, in Toronto.

The diagrams of each type are numbered 1 to 7 to show the sequence of operation.

Type "A"

Photograph *A* shows one of the 138-kv breakers in service. Figure 1*A* is a diagram of this breaker in the open position showing the main parts which are: the tank storing air at 100 lbs. per sq. in., the interrupter, and the isolating switch. In figure 2*A* the closing coil is being energized to close the breaker by admitting air from the tank to the cylinder and piston which closes the isolating switch. This coil is extremely small and becomes fully energized in a fraction of a cycle. The coil only has to move its plunger about one-eighth inch uncovering a port of one-eighth inch diameter, releasing about one-quarter cubic inch of compressed air from under a rubber diaphragm of about two inch diam. which is blown open by the opposing air pressure on the other side, thus opening the valve which admits air from the tank to the isolating switch cylinder and closes the switch. The cylinder of each pole is mounted under the bedplate of the interrupter, at line potential, as close as possible to the switch blade operated by a short link. Electrical, pneumatic, and mechanical inertia are reduced to the practical limit thus minimizing the closing time. A standard auxiliary switch to perform the usual functions, is operated from the isolating switch blade by a 90-degree rotation of the same porcelain tube (of one inch inside diameter) conveying closing air to the switch cylinder. Provision is also made for raising and lowering this porcelain tube one inch, to perform additional functions in connection with quick automatic reclosing.

The jaw contacts of the isolating switch are mounted on the cap of the porcelain cone of the current transformer; this cap is purposely made extra heavy in weight and is supported on rubber bushings to minimize mechanical shock to the porcelain due to fast operation of the switch blade. The jaws are full-floating and swivel to facilitate cracking of ice film in opening; a large sleet hood also covers the contacts.

The interrupter has three identical interrupting elements in series in the 138-kv breaker and six in the 230-kv breaker. Each element has two stationary contacts bridged by one movable contact thus making two breaks in series per element. The movable contact is rigidly secured to a steel piston rod and piston working in a bronze cylinder insulated from adjacent cylinders. Figure 3*A* shows the breaker in the closed position.

As shown in the photograph *A*, the 138-kv breaker has one tank and three blast valves. The 230-kv breaker has three separate tanks to facilitate shipping and erecting the greater length. The 230-kv breaker is built up with the same parts as the 138 kv and almost all of the parts are interchangeable. Due to the greater height, the 230-kv interrupter is brazed with diagonal stacks of standard switch insulators.

The blast valve which is the same for 230 kv and 138 kv, is built into the side of the tank with an inlet of about three square feet section. The outlet of the valve is a funnel-shaped orifice of about 8″ diameter at the valve seat which is normally closed by a thick rubber diaphragm about 20″ diameter, reinforced by a light steel disk vulcanized to the rubber. The diaphragm moves down about one inch to fully open the valve. Air pressure at 100 lbs. is maintained underneath this diaphragm, to hold it closed. The volume of air under the diaphragm is less than one-twelfth of a cubic foot. To open the breaker this small volume of air is exhausted to atmosphere by two or three one-inch diameter orifices each normally held closed by a diaphragm and coil of the same size as

Paper 41-114, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 2, 1941; made available for preprinting May 9, 1941.

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The authors gratefully acknowledge the assistance of H. Milliken, chief engineer and general superintendent of Montreal Light, Heat and Power Consolidated, in the preparation of this paper.

distortion of ten per cent, a voltage fluctuation of 90 to 140 volts, and an ambient temperature range of minus 10 to plus 40 degrees centigrade. The power consumed being eight-tenths volt-ampere at 97 per cent power factor.

As the complete instrument can be installed in a $3\frac{1}{2}$-inch case, it is well adapted for use where space is limited. The elimination of an external reactor reduces the work involved in wiring and installation.

Figure A. General view of 138-kv air-blast breaker

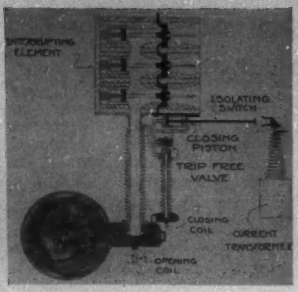

Figure 1A. Breaker in the normal open position

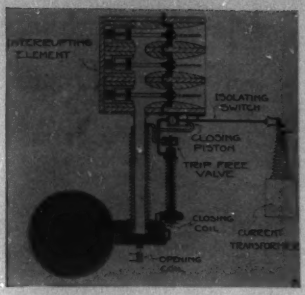

Figure 2A. Closing coil energized, isolator moving

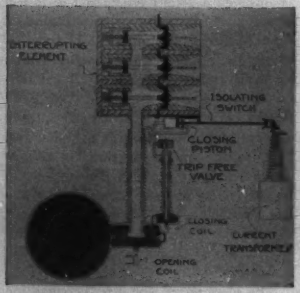

Figure 3A. Breaker in normal closed position

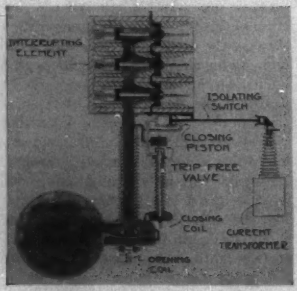

Figure 4A. Opening coil energized, air filling blast tube

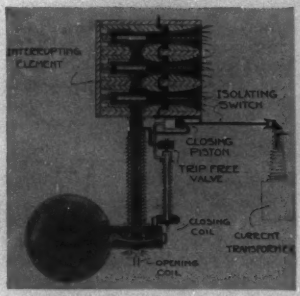

Figure 5A. Interrupter pistons open, arc drawn

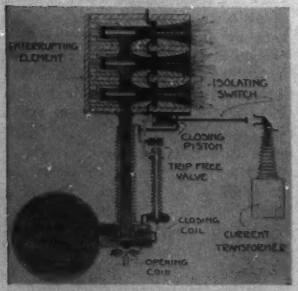

Figure 6A. Arc extinguished, isolator moving open

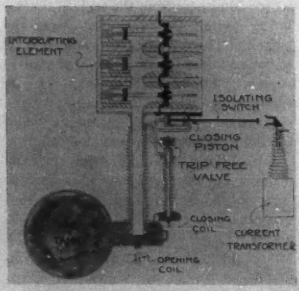

Figure 7A. Valves reset, breaker normal open

that described in connection with the valve used for closing the isolating switch. The weight of the moving parts of the blast valve is small, less than 5 pounds and the accelerating force is about 10,000 pounds, which gives an acceleration of about two thousand times that of gravity. This accounts for the very fast opening of these breakers, about one-sixtieth of a second from energizing the trip coil until parting of contacts, which of course is fast for a breaker of this large size. The interrupting element also contributes to this short opening time, the moving part having a weight of less than ten pounds and an accelerating force of about 2,000 lbs.

High-voltage air-blast breaker

For this type of breaker there are three interrupting elements in series, each individually air-operated

Figure 4A illustrates the conditions during the opening of the interrupter. The blast valve is open; a wave of air pressure is travelling up the porcelain blast tube, compressing the atmospheric air standing in the tube and header in the interrupter structure, similar to a sound wave, blasting the interrupter pistons to the left, opening the contacts and interrupting the arcs. A pressure wave is also travelling through a half inch pipe to the isolating switch cylinder but it cannot reach the cylinder in less than several cycles, leaving ample time for the interruption of the arcs before the isolating switch parts contact. This is shown in figures 5A and 6A.

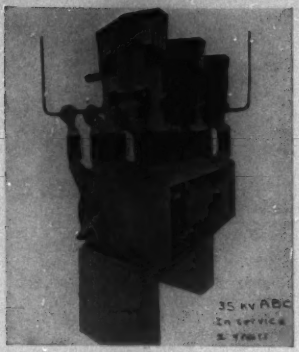

Figure B. General view of 35-kv air-blast breaker

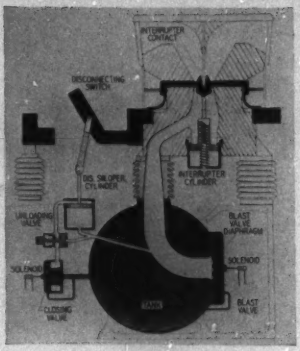

Figure 1B. Breaker in the normal open position

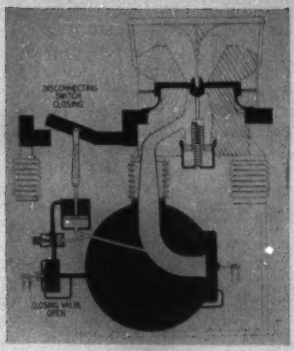

Figure 2B. Closing coil energized, isolator moving

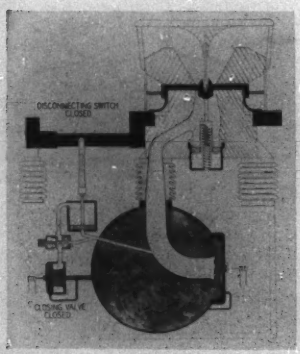

Figure 3B. Breaker in normal closed position

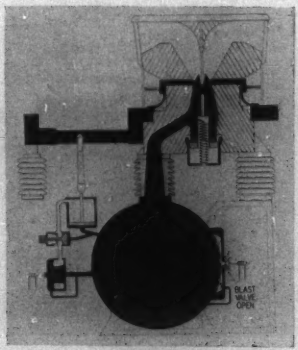

Figure 4B. Opening coil energized air filling blast tube

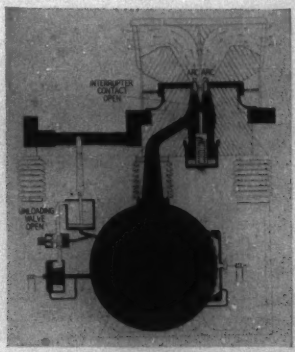

Figure 5B. Interrupter pistons open, arc drawn

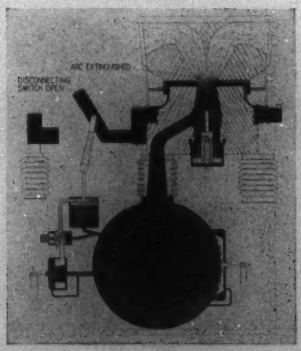

Figure 6B. Arc extinguished, isolator moving open

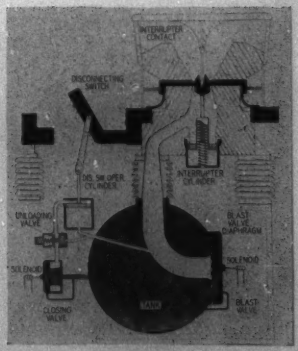

Figure 7B. Valves reset, breaker normal open

Medium-voltage air-blast breaker

This type of breaker uses only a single blast valve for all three phases and only one interrupter element per phase

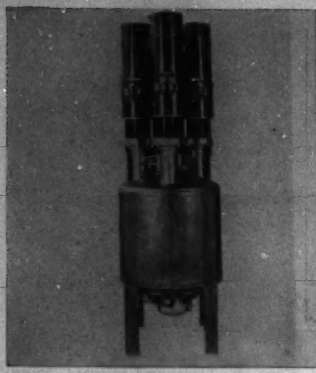

Figure C. General view of 12-kv air-blast breaker

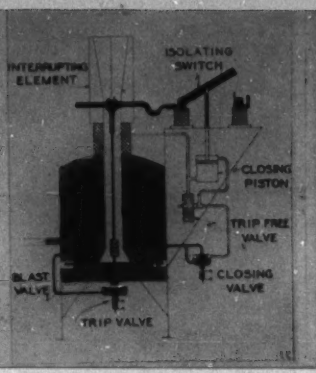

Figure 1C. Breaker in the normal open position

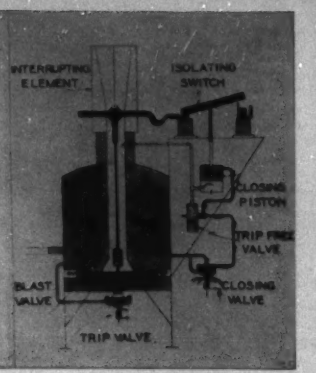

Figure 2C. Closing coil energized, isolator moving

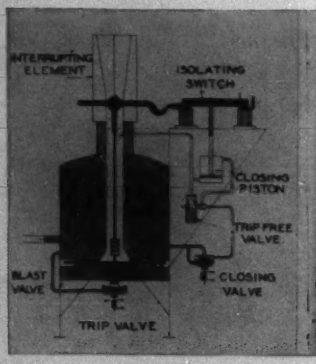

Figure 3C. Breaker in normal closed position

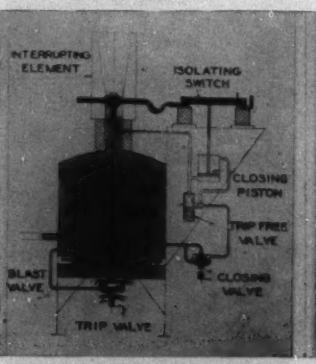

Figure 4C. Opening coil energized, air filling blast tube

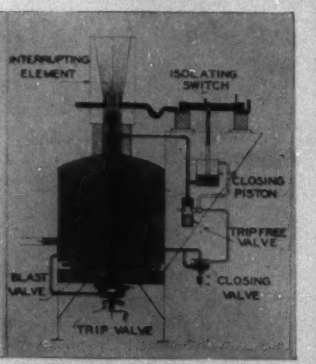

Figure 5C. Interrupter open, arc drawn

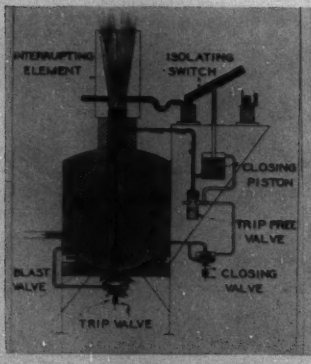

Figure 6C. Arc extinguished, isolator moving open

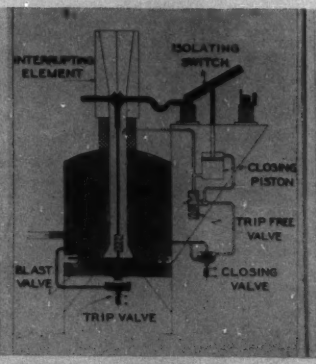

Figure 7C. Valves reset, breaker normal open

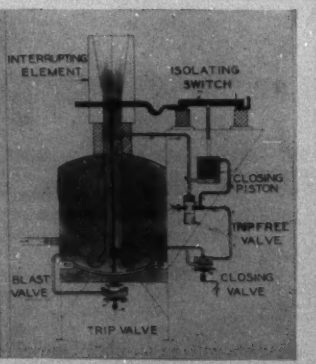

Figure 8C. OCO air trip-free valve draining closing air

Low-voltage air-blast breaker

In this type of breaker the main blast diaphragm operates the three phases of the interrupter elements

As the isolating switch is almost fully open, its auxiliary switch opens the trip circuit and the spring in the trip coil closes the trip valve permitting the re-establishing of pressure under the blast valve diaphragm by the flow from the tank. It has been found unnecessary to provide an area under the diaphragm greater than the area on top of it in order to make the diaphragm reseat, because there is an ejector effect which reduces the pressure near the center of the diaphragm due to the high velocity of the discharge and the diaphragm reseats promptly when the trip circuit is opened. Means have been developed for automatically shutting off the infeed of air from the tank to the lower side of the diaphragm while exhausting that space through the trip valve, but in service it has been found that satisfactory timing is obtained without such device. In general, the breaker can be blasted several times in quick succession before the tank pressure is reduced below the safe operating limit. When several breakers are installed in the same station, a common auxiliary storage tank is provided which quickly restores pressure in the breaker tank after which normal pressure is restored in the storage tank by the automatic starting of the compressor.

The 230-kv and 138-kv breakers are well adapted to single pole operation as there is no mechanical connection between poles. The switchboard operator can change the control from three-pole operation to single-pole operation by simply turning a control switch.

Type "B"

Photograph *B* illustrates a 35-kv breaker built by the I-T-E company which has been in successful service outdoors in New England for about two years at a location near the seashore where the salt spray constitutes a test of insulation even more severe than the St. Lawrence River mists on the higher voltage breakers. Figure 1*B* is a diagram of this 37-kv breaker in the open position. The interrupter has only one moving contact per pole; it is rigidly secured to a steel piston-rod and piston moving vertically in a cylinder which is at line potential. There is one blast valve and tank serving the three poles. The blast valve outlet divides three ways inside the tank and the three tubes pass through the tank to their respective poles. The blast valve is of the same general design as that of the higher voltage breakers, with certain modifications in detail, including springs to accelerate reseating of the diaphragm. The three poles of the isolating switch are operated by one cylinder at ground potential.

Figures 1*B* to 7*B* show the sequence of operation of this breaker. All breakers described in this paper are equipped with a pneumatic trip-free device operated by blast pressure to shut off compressed air supply to the closing end of the isolating switch cylinder and exhaust the air trapped in the closing end. The exhausting action is accelerated by the ejector effect of the nozzle in case the isolating switch closes on a short circuit.

Breakers of this same type also have been built by this company for 15 kv and 3,000 amperes. The current-carrying contacts are separate and part slightly before the interrupting contacts, all being rigidly fastened to the same operating piston-rod. In these breakers means are provided for surrounding the stationary contacts by air pressure to prevent premature parting of contacts before the moving contacts have moved away.

Type "C"

Photograph *C* illustrates a type of smaller breaker for 15 kv to 4 kv indoor service, 2,000 amperes, built by the Eastern Power Devices Limited. The main distinguishing feature of this type is the method of operating the interrupter contacts. The blast valve is of the same general design as in the other breakers except that the diaphragm has secured to its center, a steel operating tube which is rigidly connected to the interrupting contacts of the three poles through an insulating rod in each pole. When the valve diaphragm moves down it opens the blast and also mechanically opens the interrupting contacts. In order to insure that the contacts do not part before the blast arrives to interrupt the arc, a slight amount of slack is provided between the valve diaphragm and the operating rod so that the diaphragm moves down opening the valve part way before beginning to move the contacts. To minimize shock on the moving parts in opening, a spring is inserted between the diaphragm and operating tube.

Floor space is minimized by placing the tank vertically on end, the blast valve constituting the lower end of the tank. The blast valve outlet is shown in the diagrams as a single tube but actually it divides three ways passing up through the tank and out the top end of the tank in equilateral triangular formation; each of the three vertically projecting blast tubes is a 4″ standard pipe welded to the top of the tank and acts as the support for one pole of the interrupters. Each interrupter pole consists of a vertical cylinder of insulating material, 9″ inside diameter which provides sufficient space for interrupting elements of ample capacity.

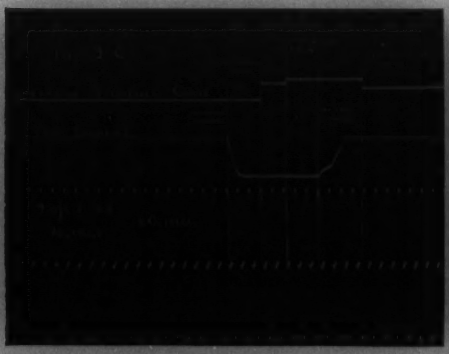

Figure 9C. Opening sequence

Figure 10 C. Oscillogram of interruption

A 2,000-amp. breaker of this type has a width of only 2′6″. This design is well adapted to various indoor layouts of stations and cell arrangements, including a draw-out arrangement of eliminating the usual disconnecting switches. This design can also be turned upside down and adapted to go into cells built for the old style oil breakers with live parts at the bottom.

Type "D"

Photograph *D* shows the general arrangement of 69-kv breakers built by the English Electric Company of Canada. It has one blast valve for the three poles, the valve being of the same design as the other breakers described. The blast tube passes horizontally through the tank to the external header tube parallel to the tank, serving the three poles through vertical stacks of porcelain blast tubes. Inside of each stack is an insulating operating rod opening and closing the interrupting contacts of the same design as in the other breakers. Each of these three operating rods is directly connected to a piston at the grounded end and in addition the three piston-rods are mechanically tied together through short links and a common shaft. The three poles of isolating switch blades are operated by a common cylinder at ground potential. The switch blade is a hollow bronze casting enclosing the hinge of a short toggle blade which makes a swiveling engagement with the stationary full-floating jaw contacts facilitating sleet cracking in opening. The blade is side opening facilitating sleet-hood protection and simplifying insulators, only two stacks per pole being required. A simple arrangement of arcing contacts has been found satisfactory in closing on short circuits with negligible burning; the operation of the isolating switch is very fast.

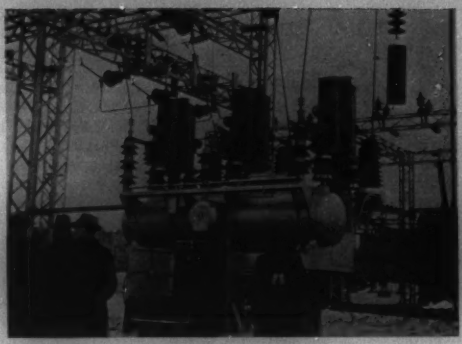

Figure D. General view of 69-kv air-blast breaker

Operating Results

The service record of breakers of this general design dates from 1934 when the first 138-kv breaker was installed. Since that time breakers of the several other voltages have been placed in service and the record is now equivalent to 20 breaker-years of service. The number of breakers recently installed and on order is 30. There have been 15 breaker interruptions reported in service, with no failures.

Interrupting Ratings

The 230-kv breaker is rated 2,500,000 kva; single-pole interrupting tests on sections of this breaker have shown interrupting capacity equivalent to more than 3,000,000 kva on the complete 3-pole breaker. The 138-kv breaker is rated 1,500,000 kva; 69-kv breaker 1,000,000 kva.

Insulation

The standard specifications for breakers of the several voltages are complied with.

Operating Time

The opening time is three cycles or less, from energizing of trip coil to current interruption. Reclosing time is within 20 cycles from energizing trip coil.

Operating Current

Closing coil or opening coil takes ten amperes or less; can be reduced to one ampere.

The Shielding of Permanent Magnets From Transient Magnetic Fields

GEORGE J. WEY
ASSOCIATE AIEE

Introduction

CONSIDERABLE progress has been made toward the development of permanent magnets which are immune to disturbing conditions, such as temperature variation, mechanical vibration, natural aging, and extraneous flux fields. Contributions to this progress include new materials, improved processing techniques, and better manufacturing controls.

Constancy of flux is in most applications quite essential. This is particularly true of electromagnetic damping, in which the damping torque varies as the square of the air gap flux. The permanent magnet of a watthour meter is an example.

Despite the fact that the modern permanent magnet is remarkably stable, there have been cases in which the magnets showed changes in strength, generally becoming somewhat weaker. Isolated instances of such changes in watthour meter magnets have been found by the electric utility companies.

About four years ago, evidence gathered by various utilities pointed to lightning discharges as the probable cause of the demagnetization. After initial laboratory tests failed to demagnetize meter magnets by passing surge currents through the windings alone, it was realized that the demagnetizing field was primarily caused by surge currents in the service wiring itself. Figure 1, curve 1 shows the amount by which forged chrome steel magnets are weakened by a single surge of the value indicated by the abscissa using the test setup shown on the figure 2.

To date, there have been no extensive studies made of the magnitude and frequency of surge currents appearing on the secondaries of distribution systems. Figure 3 shows expectancy curves for lightning discharges in distribution system primary arrester ground leads from the investigations of McEachron and McMorris.[1] These curves show that in rural areas a discharge of 5,000 amperes may be expected at any one arrester location once in 14 years and a 10,000-ampere discharge once in 30 years. In attempting to apply these expectancy curves to the distribution secondaries, however, they should be considered as extremely pessimistic because of the reduced exposure of the secondary circuit.

It is evident from a consideration of the rarity with which high current discharges appear on distribution systems that any program designed to materially reduce the number of weakened magnets found on the system secondary must be applied to a large percentage of the total exposed installations. Thus, it would be desirable to protect not only new meters but also those in service.

Since there are millions of standard forged steel magnets in service, it would be desirable that surge protected magnets should not require new techniques or tools to service them.

High Coercive Alloys

The problem of making permanent magnets impervious to transient magnetic fields has been solved in two ways by the various meter manufacturers. One method has been to make the magnet from one of the new high coercive materials, such as Alnico. The coercive force, H_c, of these alloys ranges from 400 to 600 oersteds which means that when properly applied to a watthour meter such a magnet would withstand surges up to 25,000 amperes without appreciable weakening. Another advantage of these alloys over forged magnet steel is economy of space for a given air gap energy. However, before this advantage can be realized to any appreciable extent, the whole meter must be designed with this object in view. Also, a complete new magnet design must be made and manufacturing processes developed in order to utilize the new alloys.

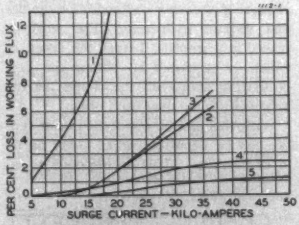

Figure 1. Demagnetization of chrome-steel magnets by transient currents

1. Unshielded
2. Plated with 0.002-inch thick copper
3. Schoop sprayed copper 0.02-inch thick
4. Copper clad (Roth process) 0.02-inch thick
5. High-speed copper plate 0.019 thick

Test waves
Curves 1, 2, 3—24x40 microseconds
Curves 4, 5—36x70 microseconds to 25,000 amperes; 30x50 microseconds 25,000 to 40,000 amperes; 20x35 microseconds over 40,000 amperes

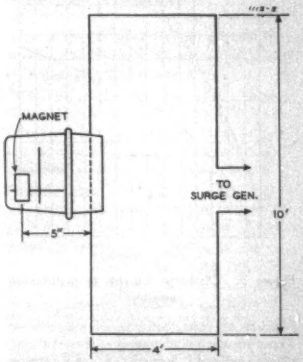

Figure 2. Setup for surge tests on permanent magnets

Electromagnetic Shielding

An alternate solution to the problem of transient fields and the one described in this paper is to use electromagnetic shielding around the existing forged steel magnets. While this principle of shielding is old,[2] it is felt that a description of its application to permanent magnets is new and may be of general interest.

The requirements of an efficient electromagnetic shield are: first, the shield must provide low resistance paths for the flow of eddy currents. Second, the shield must be continuous about the object to be shielded so the eddy currents can flow in any direction.

The above requirements immediately suggest plating the magnets with copper,

Paper 41-112, recommended by the AIEE committee on instruments and measurements, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 23, 1941; made available for preprinting May 7, 1941.

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1. For all numbered references, see list at end of paper.

since copper has low electrical resistance and a continuous sheath of the metal could be easily plated on steel. With the ordinary process of electroplating copper

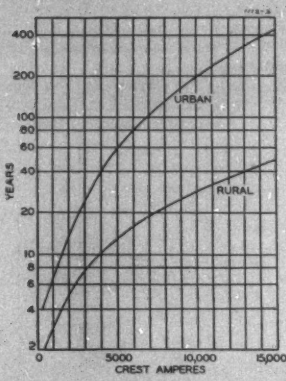

Figure 3. Discharge currents in distribution arresters

Number of years that may be expected to elapse for each discharge of at least the magnitude indicated through any one arrester

from a copper sulphate solution, however, it is impractical to build up a coat more than 0.002" thick, and even this thickness requires upward of 24 hours plating time.

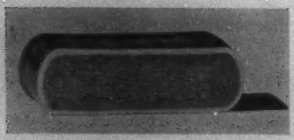

Figure 4. Cross section of plated magnet

Figure 1, curve 2 shows the shielding effect of a 0.002" thick plated copper sheath using a 24x40 wave (24 microseconds to crest, 40 to half value). By comparing with curve 1 it will be seen that such a shield is quite effective against transients.

Another method of applying a metallic coating is by the Schoop spray process. By this means metallic coatings of any desired thickness can be applied to magnets. Figure 1, curve 3 shows the shielding effect obtained by this method. Due to the porosity and consequent high resistivity of the deposited metal and the difficulty of obtaining a uniform coating, this method was considered inadequate.

Good shielding can be obtained by the use of copper-clad steel made by any of the standard commercial processes. Figure 1, curve 4 shows the shielding obtained from a 0.020" thick layer of copper formed by the Roth process. This process consists of placing a properly fluxed billet of steel in a vertical mold. After heating the mold and billet to a red heat, molten copper is poured around the billet. The mass is then rolled to the desired bar size. The principal disadvantage of copper-clad steel for magnets is that the conductivity of the copper is lowered during the heat treatment of the magnet steel. Also, the copper coat is not of uniform thickness, which reduces its effectiveness.

High-Speed Copperplating

Early experiments with a new high-speed copper-plating process invented by the E. I. du Pont de Nemours Company gave results worthy of further investigation. The high-speed copper-plating process plates from a hot alkaline bath consisting of copper and sodium cyanides and sodium hydroxide. The work is placed in a rotating barrel, the speed of which is regulated to obtain the best burnishing action on the copper as the magnets tumble over each other.

Figure 5. Left, magnet before plating; right, magnet after plating

With this process about 13.1 lb of copper can be deposited in 11 hours on 65 lb of magnets. This corresponds to an average deposition rate of 0.0017" per hour.

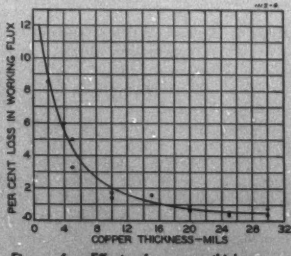

Figure 6. Effect of copper thickness on shielding of chrome-steel magnets

It was found in developing this process for the plating of magnets that the conductivity of the copper plating decreased very rapidly after the solution was used a few times. This condition was traced to an excessive concentration of sodium carbonates in the electrolyte. Excessive amounts of this compound also cause the deposit to be rough and pebbly. It was found necessary to periodically chill the solution and allow the carbonates to crystallize out.

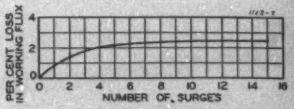

Figure 7. Effect of repeated 30x50 microsecond surges of 30,000 amperes on copper-plated chrome magnets

Figure 4 is an enlarged cross section of a plated magnet.

In order to obtain the maximum calibration adjustment on the assembled magnet, it is necessary to leave the upper pole tip unshielded. This is accomplished by placing a short length of rubber tubing over the upper pole tip before plating.

Figure 8. A complete assembly of copper-plated magnets

The tubing is thick enough to completely fill the air gap of the magnet, thus reducing the amount of material to be removed in the final grinding. Figure 5 shows a magnet before and after copper plating.

Since the effectiveness of the shielding depends on the resistance of the plating, this property is used to control the quality of the product. As absolute values are not necessary, the procedure is to measure the total ohmic resistance of the magnet between points just back of the poles using a Kelvin double bridge. The addition of the copper plating reduces the total resistance from 340 microhms for the

System Short-Circuit Currents

Proposed New Calculating Procedure for Application of Interrupting Devices and Relays

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THE current flowing in a short circuit in a simple a-c system can be expressed as a function of time in the form of three exponentially decaying components and a term which is substantially constant. These components are termed the subtransient, the transient, the d-c components, and the steady-state component. In actual systems all these terms are affected to some extent by the number of machines and the phase angles between them and also by their excitations. The phase relations between machines may change during the period of short circuit and thus introduce further complications. Automatic voltage regulators also introduce another factor which tends to increase the short-circuit current, since their action causes increase in machine excitation. Consequently, the accurate determination of short circuit current at any instant may be and usually is quite difficult.

Fortunately such rigorous calculations are not generally required to determine the proper application of interrupting devices and relay settings, for many other factors having greater proportional effect than the variations cited above contribute to the determination of the limits for rational choice of circuit breakers, expulsion protective gaps, fuses, etc. It is, therefore, perfectly proper and logical to make certain approximations in the calculation of short-circuit current to permit simple solutions of electrical systems for the purpose of applications of equipment. Such assumptions have been in general use for a considerable time and recognized by the electrical engineering profession.[1] An early approximation took the form of decrement curves which could be utilized if the reactances of the component branches of the system were known. As the knowledge of machine performance with the resolution of currents into the transient and subtransient components increased and the use of symmetrical components for unbalanced conditions became more generally known and accepted, the original decrement curves were revised[2] and placed on a more substantial basis. These curves, the present decrement curves, included provision for the determination of three-phase, line-to-line and line-to-ground short-circuit currents. At the same time other and more elaborate approximations[3,4] were offered which, while giving more accurate results, involved more extensive and complicated calculations.

The growth and interconnection of systems has resulted in a condition such that if the curves are applied according to the rules, values of impedance outside the range of the curves are often obtained, thus making the curves useless. Recourse was often made to certain expedients, such as the division of the system into several groups, each of which fed short-circuit currents into the short circuit independent of the others. These were so chosen that all the generators in a certain group were approximately the same electrical distance from the fault. In addition, frequent errors have occurred, even among those accustomed to the use of the curves, in confusing the kva of the arbitrarily chosen base on which calculations are made, with the kva of the system. The need undoubtedly exists for

Paper 41-121, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16-20, 1941. Manuscript submitted April 16, 1941; made available for preprinting May 14, 1941.

W. M. HANNA is with Consolidated Gas, Electric Light and Power Company, Baltimore, Md.; H. A. TRAVERS and C. F. WAGNER are with Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and C. A. WOODROW and W. F. SKEATS are with General Electric Company, Mr. Woodrow in Schenectady, N. Y. and Mr. Skeats in Philadelphia, Pa.

This paper is the report of a group assigned to investigate the problem under the auspices of the subcommittee on circuit breakers, switches, and fuses of the AIEE committee on protective devices.

1. For all numbered references, see list at end of paper.

steel alone to approximately 75 microhms for the combination.

Figure 6 shows the shielding effect of plated copper plotted against copper thickness. No appreciable increase in shielding is obtained after the coat is 0.020" thick.

Figure 1, curve 5 shows the shielding effect of a 0.019" thick plated copper shield using the surge values indicated on the figure.

Figure 7 shows the effect of repeated surges of the same magnitude on copper-plated magnets. Since the resistivity of the steel is fairly low (40.5 microhms/cm³), an appreciable amount of self-shielding is obtained from the steel itself. This means that the demagnetizing effect of the first surge is limited to the outermost layer of magnet steel. After the surge has passed, the inner layers of steel remagnetize the outer layer, thereby weakening the whole magnet. Succeeding surges continue the process of demagnetizing fresh layers of steel until the demagnetized layer is so thick that the eddy currents induced in it are sufficient to prevent the further penetration of the transient flux. This is the same as saying that the demagnetization continues with succeeding surges until the intensity of the transient field minus the opposing intensity of the eddy current field equals the coercive intensity of the magnet material.

A complete copper-plated magnet assembly is shown on figure 8. This magnet is entirely interchangeable with unshielded magnets of similar design. Since the magnet material is the same as that used on unshielded magnets, the air gaps may be cleaned with magnetic cleaning tools without disturbing the calibration.

Summary

It has been shown that the problem of protecting permanent magnets from transient magnetic fields has been solved in a unique manner by the use of a new high-speed copper-plating process to apply a high conductivity copper shield over the conventional forged steel magnets.

Desirable features of this solution are complete interchangeability between unshielded and shielded magnets; forged steel material is used, which is fairly easy to obtain and on which unlimited operating experience is available.

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2. HIGH FREQUENCY MEASUREMENTS, August Hund. McGraw-Hill Book Co., 1933, page 47.

the simplification, if possible, of the present methods of the calculation of system short-circuit currents. Fortunately, due to the increased use of higher speed circuit breakers and faster relaying, this need can be satisfied for an extremely large proportion of the present applications. It is the purpose of this paper to discuss this general problem and recommend simplified methods of calculation for different types of apparatus.

The modern trend of practice is to speed up materially the clearing of short circuits in order to reduce damage and maintain continuity of service. But, in general, the more quickly a short circuit is cleared, the greater is the current to be interrupted. Thus it is quite easy, by speeding up the relay system, to jeopardize the breakers by requiring them to interrupt more current than that for which they were initially chosen. Also quite often there is a tendency to save investment in breakers by the use of slow speed relays to take advantage of the decrease in short-circuit current due to its decrement with time, but even with slow speed relays, there is no guarantee that a short circuit will not change its character and initiate a high current flow in a breaker while it is opening. And there is always the danger of shortening the time setting of slow speed relays, which will tend to increase the interrupting duty on the breaker. Provision of breakers with interrupting capacity adequate for fast relaying is thus at least as essential a part of planning for the future as the usual allowance for increase in generating capacity.

This being the case, the problem of interrupting device application resolves itself into a study of what happens in a system during the first few cycles of short circuit. Even with fast relaying, modern high speed breakers for 60-cycle systems may be expected to part their contacts in times no shorter than given below:

8-cycle breakers—4 cycles (0.0666 second)
5-cycle breakers—3 cycles (0.05 second)
3-cycle breakers—2 cycles (0.033 second)
2-cycle breakers—1 cycle (0.0166 second)

In the above intervals of time, the effects of change in relative phase position and change in excitation from voltage regulators are negligible and permit eliminating their influence in the calculation of short-circuit values. Values so calculated will also be on the conservative side where some types of breakers in the above classes part their contacts in slightly longer times.

Figure 1 gives, in the full-line curves, the magnitude of the three-phase short-circuit current expressed in terms of rated current for various reactances as obtained from the present decrement curves, for the four instants specified; namely, 4, 3, 2, and 1 cycles which are related to the 8, 5, 3, and 2-cycle breakers as discussed above. The rated current and reactances are based on the system kva. Curves are given for both the total rms current and the a-c component only, the difference between the two being due to the d-c component. The larger the d-c time constant,

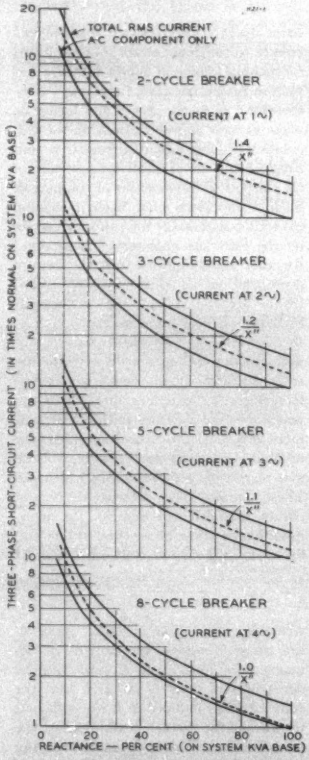

Figure 1. Comparison between decrement-curve calculations and calculations by the proposed method

the more closely is the total rms curve approached and the smaller the d-c time constant, the more closely is the a-c component curve approached. The time constant of the d-c component for which these curves were made is 0.15 second or 9 cycles. The d-c time constant may be expressed generally as equal to $\frac{1}{2\pi f}\cdot\frac{X}{R}$ in seconds, or $\frac{1}{2\pi}\cdot\frac{X}{R}$ in cycles, where X is the 60-cycle reactance and R the d-c resistance to the point of fault. Although ratios vary considerably, representative values of the ratio X/R for the major circuit elements for large equipment are given below.

	X/R	Corresponding Time Constant In Seconds	Corresponding Time Constant In Cycles
Generators	80	0.21	13
Current-limiting reactors	50	0.13	8
Transformers	16	0.04	3
Transmission line	4	0.011	0.6
Cable	1.0	0.003	0.2

When any of these elements are connected in series relation the time constants of the combination become much smaller than that of a generator alone. Even a short length of transmission line has a marked effect upon the d-c component of current and a very appreciable effect upon the total short-circuit current. Table I shows the time constant of a particular combination for a fault at the generator, at the transformer terminals, and at two points out on an overhead line.

The Power Circuit Breaker Interrupting Problem

The reactances of figure 1 are based on the kva of the connected generator capacity. When the fault is near a generator the reactance is likely to be small and the d-c time constant large so that for small reactances the actual short-circuit current would approach the values given by the total current curves of figure 1. If, on the other hand, the fault is on the transmission line, the reactance is large and the time constant small. Thus, for large reactances the actual currents approach the values given by the a-c component only. The intermediate curves (dotted) of figure 1 for circuit breaker opening times of 4, 3, 2, and 1 cycles have been computed by the relation $1.0/X''$, $1.1/X''$, $1.2/X''$, and $1.4/X''$ respectively, in which X'' represents the system reactance to the points of fault, subtransient reactances being used for all generators. The factors in the numerators were arbitrarily chosen so that the curves lay between the curves for the total current and a-c component of current, and so the values were numbers that can be remembered easily.

In these curves the effect of the arc drop, which may be quite considerable in decreasing the d-c time constant, has been neglected. For a reactance of 30 per cent an arc drop of only 1.5 per cent in combination with one-half per cent resistance

in the system is all that is required to reduce the d-c time constant from the nine cycles used in the present decrement curves to three cycles. On a 440-volt basis this is equivalent to but 6.6 volts, a value that is easily attainable. A reasonably conservative value of arc drop is about 20 volts per inch so that on a 13,800-volt circuit, 1.5 per cent drop requires only about six inches of arc length.

Having shown through the medium of the decrement curves that the relations for 4, 3, 2, and 1-cycle opening times apply quite well for simple systems, the justification has been established for applying the same relations to more complex systems. The use of these simple relations circumvents practically all the disadvantages of the decrement curves enumerated previously. With this method of calculating it is necessary only to obtain the equivalent reactance, expressed in any manner, regardless of the system, and apply the appropriate factor to the reciprocal of the reactance.

The foregoing simplified rules cover practically all applications. For the few remaining, it is sometimes desirable to know the short-circuit current for times longer than four cycles. For these special cases, the present decrement curves[2] or more elaborate methods may be utilized.[2,4,5,7] However, these methods are discouraged in favor of the rules proposed in this paper.

In most cases, faults occur at a point in the system for which a certain amount of other apparatus intervenes between the generators and the point of fault, in which case, the d-c component decays rapidly and the actual current approaches the a-c component. Even if the fault occurs on a generator bus, it is likely that other generators contribute to the short-circuit current through transformers, transmission lines, or cables. Therefore, the calculated values of current will be conservative for most cases.

In extreme cases where all the fault current is produced by large generators located at the point of fault, an accurate calculation with all assumptions on the safe side might show values as much as 20 per cent higher than the values given by this procedure. For the most conservative practice, therefore, when this condition is approached the results may be increased or other methods of calculation used.

In the curves of figure 1 adequate allowance has been made for non-synchronous load. For most central station applications, the additional contribution from synchronous motors will be negligible but where there is an appreciable contribution from them, they should be taken into account. In industrial applications, synchronous motor contribution may be of the same order of magnitude as that from generators and hence must be taken into account.

Synchronous motors are usually operated at about unity power factor; hence the voltage behind their subtransient and transient reactances is but little above terminal voltage. They tend to increase the power factor of the load; hence indirectly they reduce the internal voltage of the system generators. In general, they are much smaller units than generators; hence all of their time constants are faster and the decay of their short-circuit current is more rapid. For all of these reasons, it is justifiable to make somewhat

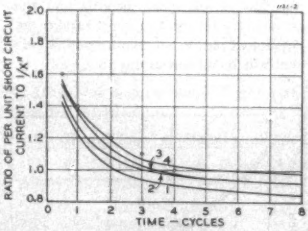

Figure 2. Three-phase short-circuit current from generators fully loaded at rated power factor

Arcing fault at one-fourth mile per kilovolt of transmission line

1. Steam-turbine generator, 0.8 power factor without transformer
2. Steam-turbine generator, 0.8 power factor with transformer
3. Hydroelectric generator, 0.9 power factor without transformer
4. Hydroelectric generator, 0.9 power factor with transformer

Circles show points proposed for calculating duty of equipment

less allowance for the short-circuit current of synchronous motors than for generators. Transient reactance may, therefore, be used in calculating their contribution.

The contribution of induction motors can always be safely neglected at times of two cycles or more.

The Momentary Problem

For many purposes, it is necessary to know the maximum possible rms current which can flow in the circuit. This is given by the current, including both a-c and d-c components, as calculated at one-half cycle. Allowing for overexcitation of generators on account of load, the rms value of current as calculated for zero time is about 1.8 times the value calculated by dividing leg voltage by subtransient reactance. As there will always be some decay even in the first half cycle, however, 1.6 times this value gives a safe figure.

In some instances, as when transmission line or cable reactance is an important factor in the limitation of current, the factor 1.6 may be higher than necessary.

In such applications, at 5,000 volts and below, the ratio of reactance to resistance is sufficiently low so that the d-c component decreases very greatly during the first half cycle. Thus within this voltage range, and except where the bulk of the power is supplied by generators at the point of fault, a standard factor of 1.4 may be used instead of 1.6. A standard factor is particularly desirable in consideration of the difficulties of obtaining actual resistance figures and the distribution of the d-c component among contributing short-circuit sources.[8]

Examples

All of the foregoing has been carefully checked by the calculation of specific examples. Figure 2 has been calculated for four representative simple cases as follows:

1. A representative turbine-generator with both transmission and fault at generator voltage.
2. A representative turbine-generator with a step-up transformer and both transmission and fault at 230 kv.
3. A representative hydro-electric generator with both transmission and fault at generator voltage.
4. A representative hydro-electric generator with a step-up transformer and both transmission and fault at 230 kv.

In each case the transmission line was assumed to have a length of one quarter mile per kilovolt and to have sufficient copper section to carry the entire generator output (either in one line or in several parallel lines) at a current density of 1 ampere per 1,000 circular mils. An arcing fault is assumed with an arc drop of 150 volts at generator voltage and of 2,000 volts at 230 kv.

The points corresponding to the coefficients 1, 1.1, 1.2, 1.4 and 1.6, at 4, 3, 2, 1, and $^1/_2$ cycles respectively are shown on figure 2, and it will be observed that they represent with reasonable accuracy the currents obtained at their respective times.

Figure 2 may be considered representative of the general case in which although some power may be generated near the point of fault, the major part of the short-

circuit current comes from some distance away. Figure 3 has been calculated on a similar basis but without any transmission line between generator and fault point. Here it will be observed that the currents are somewhat higher, particularly for times from two to four cycles. It is for this reason that the recommendation is made that some additional allowance be made when the major part of the short-circuit current is obtained from large machines located at the point of fault.

Selection of Apparatus

It is suggested that the following procedure be followed in calculating short-circuit currents for use in applying various kinds of equipment.

Circuit-Breaker Interrupting Capacity

While there is a wide variation in system conditions, the following calculation will usually give a conservative value of required interrupting capacity.

(1). Calculate the highest value of initial rms symmetrical current on the basis of no load, normal voltage, whether for a three-phase, double-line-to-ground, line-to-line, or single-line-to-ground fault, using subtransient reactances for all synchronous generators. Use transient reactance of synchronous motors when their short-circuit contribution must be considered.

(2). Multiply by the appropriate factor for 60-cycle systems from those given below:

8-cycle breakers	1.0
5-cycle breakers	1.1
3-cycle breakers	1.2
2-cycle breakers	1.4

(3). When the condition is approached of a short-circuit fed solely by large machines at the point of fault, these results may be increased up to 20%.

(4). Low voltage (600 volts or less) air circuit breakers are often instantaneous in operation and part contacts during the first half cycle. These breakers, however, are rated on the basis of average current in the three phases, and circuits on which they are installed rarely have X/R ratios exceeding ten. This corresponds to an average rms current during the first cycle equal to 1.23 times the symmetrical current. Breakers may therefore be applied on the basis of $1^1/_4$ times the three-phase initial symmetrical current using subtransient reactance and including both synchronous and induction motors.[5]

In order to co-ordinate this method of application of low voltage breakers with the conventional method used for other types of breakers, it is interesting to note that an average current for the three phases equal to $1^1/_4$ times the symmetrical current corresponds to a total rms current in the phase carrying the maximum unsymmetrical current equal to 1.4 times the initial symmetrical component.

In making the calculation for the equivalent system impedances, it should be remembered that at low voltages small impedance values become of importance and all elements of the circuit including current transformers, disconnects, switches, circuit breakers, bus runs, lead wires, et cetera should be taken into consideration.

Mechanical Stresses and Momentary Rating of Circuit Breakers

The initial mechanical stresses due to the flow of electrical currents and the momentary rating of a circuit breaker are dependent on the maximum possible current which can flow at any time.

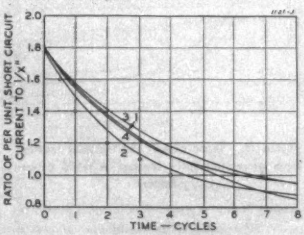

Figure 3. Three-phase short-circuit current from generators fully loaded at rated power factor

Arcing fault at generator or transformer terminal

1. Steam-turbine generator, 0.8 power factor without transformer
2. Steam-turbine generator, 0.8 power factor with transformer
3. Hydroelectric generator, 0.9 power factor without transformer
4. Hydroelectric generator, 0.9 power factor with transformer

Circles show points proposed for calculating duty of equipment

(1). Apart from cases covered by (2) below, the current to be used is 1.6 times the maximum value of rms symmetrical current using subtransient reactance values of both synchronous and induction machines.

(2). At 5,000 volts and below a factor of 1.4, instead of 1.6 should be used except on busses to which the major portion of total fault current is supplied either by directly connected synchronous machines or through reactors.

Directly connected synchronous machines are to be considered as those supplying fault current directly or through lines and transformers which reduce the contribution from those machines by less than 50%.

Protector Tubes

Inherent limitations of protector tubes require that a maximum and a minimum current rating be assigned to each tube for a given voltage. Because of the speed with which these devices become operative, it has been found possible to incorporate the variability of the d-c component into a rating which involves only the initial rms symmetrical a-c component of short-circuit current.[6]

Tubes should be applied so that the symmetrical short-circuit current at the point of installation of the tube, calculated on the basis of subtransient reactance for all combinations of connected synchronous machines and lines, should fall between the two limits assigned to the tube.

Fuses

Fuses are rated on total current and as the times involved are very short, their required interrupting capacity should be based on the total rms current at one-half cycle.

(1). In the general case, the current to be used is 1.6 times the maximum value of rms symmetrical current, using subtransient reactance for all machines, and including both synchronous and induction motor contributions.

(2). For fuses rated 15,000 V. or below with interrupting ratings not exceeding 3,000 amperes (except when applied on a generator bus) the resistance introduced by line and transformer is so great that the rms current of a maximum displaced wave in the first half cycle will not exceed 1.2 times the calculated symmetrical current, using subtransient reactance, and application on this basis may be considered safe.

Preliminary Relay Setting

High speed current actuated relays can be given settings based on, first, the highest initial symmetrical current, using subtransient reactance at maximum system conditions, and second, on the lowest initial symmetrical current using subtransient reactance for minimum system conditions. Time over-current relays are usually set by use of similar values of symmetrical current using transient reactance values.

The settings of distance and pilot wire relays are assumed independent of the magnitude of short-circuit current but their accuracy may be impaired if the currents are outside of the range for which they were designed. This range is determined by the maximum initial symmetrical current for maximum system conditions and the minimum initial symmetrical current for minimum system conditions using sub-transient reactance values if the relays are high speed, or similar values of current calculated with transient reactance values if slower relays are used.

For bus differential relays it may be necessary to make an accurate calculation of both a-c and d-c components for assurance that operation will be satisfactory.

Conclusions

The precise determination of short-circuit currents involves a calculation so laborious as to be wholly impractical. Thus some approximation is required and a degree of judgment is required in the application of any method proposed.

The following rules are proposed for the various applications:

A. Circuit-Breaker Interrupting Capacity

Determine highest value of rms symmetrical current for any type of fault using subtransient reactance for synchronous generators and transient reactance for synchronous motors.

1. General Case. Multiply by the appropriate factor for 60-cycle systems from those given below:

8-cycle breakers	1.0
5-cycle breakers	1.1
3-cycle breakers	1.2
2-cycle breakers	1.4

2. Short-Circuits Fed Predominantly by Large Machines at the Point of Fault. Increase results of the general case up to 20%.

3. Air Circuit Breakers Rated 600 Volts or Less. Apply on basis of average rms current in all three phases, which may be taken as 1.25 times the rms symmetrical current.

B. Mechanical Stresses and Momentary Rating of Circuit Breakers

Determine highest value of rms symmetrical current for any type of fault using subtransient reactance for both synchronous and induction machines.

1. General Case. Multiply by 1.6.

2. At 5,000 Volts and Below Unless Fault Current Is Fed Predominantly by Directly Connected Synchronous Machines or Through Reactors. Multiply by 1.4.

C. Protector Tubes

1. Maximum Rating. Use the highest value of rms symmetrical current determined as in *B* with no multiplying factor.

2. Minimum Rating. Use the lowest value of rms symmetrical current determined as in *B* for minimum system conditions, with no multiplying factor.

D. Fuses

Determine highest value of rms symmetrical current as in *B*.

1. General Case. Multiply by 1.6.

2. At 15,000 Volts or Below With Interrupting Ratings Not Exceeding 3,000 Amperes. Multiply by 1.2.

E. Basis for Preliminary Relay Settings

1. High Speed Current Actuated

(*a*). Highest rms symmetrical current based on subtransient reactance at maximum system conditions.

(*b*). Lowest rms symmetrical current based on subtransient reactance for minimum system conditions.

2. Time Overcurrent. Make the same calculations as for high speed relays, but use transient reactance.

As compared with the latest decrement curves,[3] this method of calculation of short-circuit currents is somewhat simpler and should reduce considerably the possibilities of misapplication.

This method is in accordance with the present trend toward high speed relaying and eliminates the possibility of exceeding breaker interrupting capacities by modernizing the relay system after installation of the breakers.

It recognizes the acceleration of the decay of the d-c component of short-circuit current caused by the relatively high resistance of circuit elements other than the generator.

Table I. Effect of Location of Fault Upon D-C Time Constant

Location of Fault	Impedance to Point of Fault X	Impedance to Point of Fault R	X/R	Time Constant In Cycles	Time Constant In Secs
Generator terminals	20	0.25	20/0.25	13	0.21
High-voltage side of transformer	28	0.75	28/0.75	5.9	0.10
Inclusion of line having 5 per cent reactance	33	2.0	33/2.0	2.6	0.044
Inclusion of line having 10 per cent reactance	38	3.2	38/3.2	1.9	0.031

All impedance on same base as generator.

In view of these advantages it is believed that this method will prove more satisfactory in practice than the present standard.

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Power-Circuit-Breaker Ratings

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CIRCUIT breaker application is being simplified. A subcommittee of the protective devices committee of the AIEE has studied methods of calculating short circuit currents and has prepared a report which presents a simplified procedure based on standardized contact parting times and typical current decrements.[1] To facilitate the use of this method, circuit breakers should have ratings which conform to the short circuit characteristics assumed in the calculations. At the present time, while the industry is preparing a revised list of short-time current ratings for circuit breakers, an opportunity exists to correlate the short circuit ratings so that a breaker selected for adequate interrupting current by the new method automatically has ratings adequate for the other short circuit currents.

The rating of a power circuit breaker as given by AIEE Standard 19-200 includes the following items:

(*a*). Rated voltage.
(*b*). Rated frequency.
(*c*). Rated continuous current.
(*d*). Rated short-time current.
(*e*). Rated making current.
(*f*). Rated interrupting current.

In addition definitions are given for the rated latching current and two short-time currents (the rated momentary current and the rated five second current).

The first three of these items are independent of each other. Breakers can be designed for any combination of rated voltage, rated frequency, and rated continuous current.

The rated making, momentary, five second, and interrupting currents are interdependent, being values of the maximum short circuit current permissible for the breaker.

The maximum short circuit current is determined by the impedance of the circuit and by the characteristics of the rotating machines supplying power to the short circuit. The initial current is composed of an a-c component determined by the subtransient reactance of the circuit, and a d-c component determined by the point on the wave at which the transient starts and by the circuit inductance and resistance. Both components are a maximum at the beginning and consequently the total rms current also is a maximum, figure 1.

This current during the first cycle is important as it is the maximum current to which the breaker will be subjected and corresponds to the rated momentary current and rated making current. In AIEE standards, "The rated momentary current is the maximum rms total current which the breaker shall be required to carry for any time however small up to one second.—" This current may be initiated either by a short circuiting of the system through some external means or by the breaker closing and completing a short circuit. Consequently, the first cycle current is also the current which the breaker must be capable of closing. By AIEE definition, "The rated making current of an oil circuit breaker is the maximum rms current including the d-c component against which the breaker must be capable of closing, without the welding of or undue damage to the breaker or contacts, with rated control voltage at the closing mechanism." Therefore, the rated momentary current and the rated making current should be at least equal to the maximum current which can be obtained during the first cycle.

Not all breakers are required to close completely and latch when making the rated current. For breakers having relatively low short circuit currents, the electromagnetic and other forces tending to oppose the closing of the circuit breaker may not impose much additional load on the closing mechanism and no difficulty may be encountered in the complete closing and latching of the breaker. Such breakers would have rated latching currents equal to rated making currents.

High interrupting capacity breakers for 15-kv service and below, have to make currents which may impose electromagnetic forces greatly in excess of the other forces opposing the closing, and may require a driving force considerably in excess of that needed for normal service. In this class of breakers, the closing and latching under short circuit conditions is a much more serious problem. The most advantageous position for carrying the current is with the contacts normally closed and the breaker latched, but with high speed tripping of the breaker it may be possible, without completely closing the breaker, to carry the current for the duration of the short circuit. However, the breaker contacts must be closed sufficiently to carry the short circuit current without undue burning or welding until such time as the short circuit is cleared elsewhere or the breaker tripped. In such cases the breaker will perform satisfactorily without latching and a rated latching current equal to the rated making current is not essential. Consequently, the rated latching current has no definite relation to the maximum short circuit current or to the rated interrupting current.

The sustained short circuit current must be carried by a breaker if it is not tripped. From its initial value, the current will decrease with the decreasing d-c and a-c components. The d-c component decreases approximately as a logarithmic function. The amount that the a-c component decreases will depend upon the effect of the short circuit on the generators. This effect is small if the generators do not form the principal limiting impedance and the a-c component may be sustained throughout the duration of the short circuit. Consequently, the maximum current which the breaker will be expected to carry for more than a few cycles while the d-c component is dying out, is the initial value of the a-c component. This value of the current corresponds to the 5 second rating of the breaker. By AIEE definition, "The rated 5 second current is the rms total current including the d-c component which the breaker shall be required to carry for 5 seconds." With increasing speed of breaker tripping this item is losing its significance.

Between the initial and the sustained currents is a current which the breaker must be able to interrupt. It is of great importance as it corresponds to the rated interrupting current which, by AIEE definition, "is the highest rms current at a specified operating voltage which the breaker shall be required to interrupt under the operating duty specified, and with a normal frequency recovery voltage equal to the specified operating voltage. The current shall be the rms value including the d-c component at the instant of contact separation as determined from the envelope of the current wave." The time at which the contacts separate and at which this current is measured depends upon the speed with which the breaker is tripped. It may be in the first cycle in the case of extremely high speed breakers, but is

Paper 41-116, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 15, 1941; made available for preprinting May 12, 1941.

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1. For all numbered references, see list at end of paper.

generally somewhat later in the short circuit. The interrupting current is between the initial and the sustained values of the current.

The basic rating of a circuit breaker is its interrupting capacity at rated voltage. The interrupting capacity determines the strength of the parts which must carry the short circuit and withstand the forces incident to the interruption of the current. The voltage determines the clearances required for insulation. The normal rated current is a less important factor in determining the size of the breaker, although it does determine to a large extent the cross section of the conducting path, the size of the conductors through the bushings, and the size of the contacts within the breaker. Therefore, the rated interrupting current at rated voltage is the basic rating, and establishes the principal dimensions of a group or class of breakers. Various modifications of this basic design are made to take care of variations in the normal current carrying capacity. For example—a breaker may be developed and tested for an interrupting ability of 500,000 kva at 15 kv and minor modifications will give the various rated normal currents.

Circuit breakers are frequently used at service voltages less than their rated voltage. At these lower voltages, the difficulty of interrupting a given current is less and higher rated interrupting currents can be assigned. Constant kva, or a rated interrupting current varying inversely with service voltage, is customarily assumed. The wider the range of service voltages at which constant kva is maintained, the greater the range of currents which must be interrupted by the breaker. For best designs which have as little compromise as possible, it is desirable to limit the interrupting current, and a limit is established which permits the use of the breaker at full kva down at least to the next lower standard voltage. This maximum permissible current is called the interrupting capacity current limitation and is about 1.5 times the rated interrupting current at rated voltage, but varies, specially for 15-kv breakers which cover a wider voltage range. This rating is one value of the highest short circuit current which the breaker can be required to pass.

The interdependent items of the circuit breaker rating, making current, momentary current, interrupting current, and five second current correspond to currents measured at various points on the short circuit transient current. If definite ratios exist among these values, the ratings of the circuit breaker should correspond to these ratios so that no one of the items becomes the limiting factor and so that if a breaker is selected for adequate interrupting capacity, it will automatically be able to make and to carry the currents associated with that interrupting capacity.

These requirements are related, but in the past variable times allowed for the tripping of the circuit breaker resulted in various durations of the length of the short circuit prior to the parting of the contacts and consequently a variation in the ratio between the initial current and the interrupting current. Consequently, it has not been possible to use definite ratios and any one of the ratings has been able to prevent the application of the breaker on a particular service.

Table 1. Favorable Relations of Interdependent Circuit-Breaker Ratings

Rating Item	Current: Measured After Start of Short Circuit at Time Interval of (Cycles)	Current: Ratio of Rating Item to Interrupting Capacity Current Limitation	Current: Ratio of Rating Item to Rated Interrupting Current (Approximate)*
8 Cycle breakers			
Rated making current	0.5	1.6	2.4
Rated momentary current	0.5	1.6	2.4
Rated interrupting current	4	0.67	1
Interrupting capacity current limitation	4	1	1.5
Rated five second current	60	1	1.5
5 Cycle breakers			
Rated making current	0.5	1.45	2.2
Rated momentary current	0.5	1.45	2.2
Rated interrupting current	3	0.67	1
Interrupting capacity current limitation	3	1	1.5
Rated five second current	60	0.9	1.35
3 Cycle breakers			
Rated making current	0.5	1.33	2.0
Rated momentary current	0.5	1.33	2.0
Rated interrupting current	2	0.67	1
Interrupting capacity current limitation	2	1	1.5
Rated five second current	60	0.83	1.25
2 Cycle breakers			
Rated making current	0.5	1.14	1.7
Rated momentary current	0.5	1.14	1.7
Rated interrupting current	1	0.67	1
Interrupting capacity current limitation	1	1	1.5
Rated five second current	60	0.72	1.08

* The ratio beween the rated interrupting current and the interrupting capacity current imitation is a variable depending on the range of service voltages at which full interrupting kva is available. The table uses the ratio 1.5 which is the most common value, but it must not be assumed that this ratio applies to all breakers. Individual cases have conditions which justify using either arger or smaller ratios.

In the report referred to previously on the new method of calculating the current, the variable of the time of parting contacts has been eliminated by the assumption of definite contact parting times dependent only on breaker speed; after 1, 2, 3, and 4 cycles for 2, 3, 5, and 8-cycle breakers respectively. Likewise, the probable ratio between the initial a-c component and the total rms current during the first cycle and at the end of each of these cycles has been established. This new method assumes that the maximum asymmetry which can occur will make the total rms value of the current, at the time of the maximum peak, 1.6 times the a-c component, and that at the end of the first and succeeding cycles, this multiplying factor becomes 1.4, 1.2, 1.1, and 1.0. Consequently, the ratio of the current during the first cycle to the interrupting current for breakers parting contacts after 1, 2, 3, and 4 cycles are (1.6/1.4=)1.14, 1.33, 1.45, and 1.6, respectively. These factors are, therefore, the ratio of the initial current to the interrupted current of 2, 3, 5, and 8-cycle breakers respectively. They represent the minimum ratios between rated momentary current and rated interrupting current which permit utilization of the full rated interrupting current.

The values assigned to the interdependent items of a circuit breaker rating should be based on the interrupting capacity as this is the most important item. The interrupting capacity current limitation is determined from it by the range of voltages at which the breaker is to be used. This value is one measurement of the heaviest short circuit current which will be passed through the breaker. From it, the rated making, momentary, and five second currents can be obtained by use of the suitable factors. Table I shows the relations between these interdependent items as derived from the data in the report on the calculation of the interrupting current.

When low voltage breakers are used at service voltages, much below rated voltages, the making current may be high and require a very powerful closing mechanism. When used near rated voltage, the breakers may require much less energy for closing the corresponding making current. Such breakers could be adjusted to the requirements of the service by limiting the power input to the closing mechanism to that required for a making current corresponding to the rated interrupting current at service voltage. The saving in energy and wear on the breaker may justify this change which amounts of imposing a special rated making current and a special interrupting capacity current limitation which are determined by the reduced closing ability.

With ratings assigned in accordance with short circuit characteristics, circuit

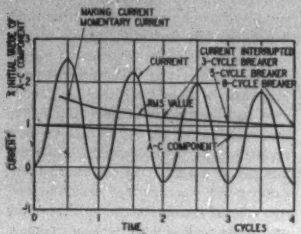

Figure 1. Short-circuit current

breaker application is simplified. Providing the current is calculated by the new method, the breaker can be selected on the basis of its rated interrupting capacity at the system voltage and the ratings of making current, momentary current, and five second current will automatically be adequate.

Since the rated making and momentary currents given in table I correspond to the interrupting capacity current limitations, they usually are higher than are required when a breaker is applied near rated voltage. When interrupting currents, calculated on the assumption of fast tripping, slightly exceed breaker ratings, a more detailed calculation using decrement curves might reveal that the making capacity is adequate and that the interrupting current is down to the breaker rating if a time delay of a few cycles is used.

If the advantages of the new method of short circuit calculation are demonstrated by experience and the method becomes used generally by the industry, another interesting possibility for the further simplification of breaker application should be considered. It gives exactly the same results as those obtained when breakers having ratings assigned in accordance with the assumed current transient are applied by the new method of calculation, but it eliminates from the calculation of the currents the factors dependent on breaker opening time and on special decrements for low voltage circuits.

Breakers could be applied on the basis of the initial a-c component of the short circuit current. The short circuit current calculations could be only the dividing of the voltage by the subtransient reactance to obtain the initial a-c component. The breaker ratings could consist of:

(*a*). Rated voltage.
(*b*). Rated frequency.
(*c*). Rated continuous current.
(*d*). Rated initial a-c component of short circuit current at rated voltage.
(*e*). Rated maximum initial a-c component of short circuit current at reduced voltage.
(*f*). Rated interrupting time.
(*g*). Rated latching current.

Breaker application could consist of selecting a breaker having these items at least as large as the system requirements. Circuit clearing time would depend on the speed of the breaker selected and the current calculation would be the same for 2-, 3-, 5-, and 8-cycle breakers.

Standardization rules could require of the manufacturer that his breakers be capable of closing carrying and interrupting currents having the rated a-c component at rated voltage and the a-c component current limitation at a corresponding lower voltage. Under these suggested rules, breakers would be capable of making a circuit having a total rms current equal to 1.6 times this maximum a-c component. They would be capable of carrying this momentary current. They would be capable of interrupting a total rms current equal to that specified for their contact parting time. They would be capable of carrying the a-c component for five seconds. Demonstrating or proving the performance of the circuit breakers would require these currents to have total rms values bearing the correct relations to the rated a-c component. On classes of breakers where special decrements are justified, for example 5 kv and below, the design of the breaker could be based on the special decrement characteristics and no change would be required in the current calculations. In other words, the requirements and results could be the same whether only the a-c component is specified and the testing requirements define the factors existing between the various currents, or whether as at present the various current values are calculated and checked for each application. Consequently, if the breakers were given rated initial a-c components of short circuit current at rated voltage and rated maximum a-c components at reduced voltage, the making, momentary, interrupting, and five second ratings could be eliminated.

In brief, the requirements would be determined by the initial a-c component of the short circuit current and a breaker selected which would have an adequate rated a-c component and which would be designed for making, carrying, and interrupting the corresponding total rms currents.

Conclusions

The ratings of a circuit breaker can be so correlated that full use can be made of the abilities of the breaker. With the new method of calculating the required interrupting capacity, and with breaker ratings assigned in accordance with the same current decrements, breaker application will be greatly simplified.

If, after trial, the new method of current calculation supplants the present method, a still further simplification in application can be obtained by rating a breaker on the initial value of the a-c component of the short circuit current which it can close, carry, and interrupt.

Reference

1. System Short-Circuit Currents, W. M. Hanna, H. A. Travers, C. F. Wagner, C. A. Woodrow, and W. F. Skeats. AIEE Transactions, volume 60, 1941 (September section) pages 877–81.

Lightning to the Empire State Building

K. B. McEACHRON
FELLOW AIEE

Synopsis: Lightning to the Empire State Building in New York City has been under investigation since 1935. Boys camera photographs of 62 strokes have been taken and 99 oscillograms. Twenty of these were taken simultaneously with photographs of the same stroke. Upward step leaders were discovered and continuing strokes were shown to be in the nature of a direct current arc. A brief résumé of the more important results up to the end of the 1937 season is given.

The paper is chiefly concerned with the oscillographic results of the 1938 and 1940 seasons. The low speed oscillograph in the Empire State Building recorded 17 of the 20 strokes to the building while the high speed oscillograph recorded 41 current peaks in 13 strokes.

1. Of 49 strokes recorded oscillographically during the years 1937–40, no stroke has been entirely positive although 41, or 84 per cent, were entirely negative. The first recorded current peak in stroke 13 was positive and had a crest current of 58,000 amperes.
2. Fifty per cent of the 49 strokes had charge of 25 coulombs or more, the maximum charge measured being 164 coulombs. These values are for the total stroke and not for current peaks.
3. Ninety-one per cent of all strokes recorded to the Empire State Building are classified as continuing, i.e. had a low current component.
4. Fifty per cent of the current peaks were found to have a crest current of 7,000 amp or more, while only 25 per cent of the 33 peaks measured in 11 strokes had a duration exceeding 40 microseconds.
5. The plotted data show that 50 per cent of the current peaks had a charge of 0.13 coulomb or more to half current value, although 5 per cent showed more than 1.5 coulombs.
6. A time of at least 1 microsecond is required to reach crest in 50 per cent of the current peaks, while 65 per cent reach the first crest in a time not greater than 1.5 microseconds—the time to crest of the present standard.
7. The results obtained show that rates of rise of the order of 10 to 20 kiloamperes per microsecond will be encountered quite frequently, and 30 to 40 kiloamperes per microsecond occasionally.
8. Errors as great as ±50 per cent may occur in connection with the highest rate of rise measurements; errors in connection with some of the other measurements may be as great as ±25 per cent, although most of the results will be more accurate than indicated by these figures.
9. It is pointed out that direct stroke data may be applied to transmission and distribution circuits if proper allowances are made for division of currents in the various paths including the effect of grounded neutral transformers. The current to be handled by lightning arresters will in general be much smaller than those measured in the direct stroke.

IN February 1939, the author published in the *Journal* of the Franklin Institute a paper[1] entitled "Lightning to the Empire State Building," and in May 1940 with K. G. Patrick, a book[2] titled "Playing With Lightning." These describe the Empire State investigation in some detail, while the instruments used have been described by Hagenguth,[3] Kettler,[4] and Flowers.[5] Therefore, only a brief mention will be made of the apparatus used, and a summary given of the important results obtained.

Equipment

At the Empire State Building are located two oscillographs—one arranged to record continuing currents up to one second duration, and the other to record the wave shape of individual current peaks. These have been called the low and high speed oscillographs respectively. At present both are of the hot cathode-ray type, although for several years the low speed oscillograph was of the electromagnetic type using a crater lamp for illumination. A schematic diagram of the operation of the high speed oscillograph is shown in figure 1. This equipment successfully[4] recorded in 1938 a multiple stroke consisting of (12) successive current peaks in 0.28 sec. Both of the oscillographs are connected to a non-linear shunt composed of thyrite and a linear shunt in parallel. With these shunts the low speed oscillograph records over a current range of 50 amps. to 24,000 amps., while the high speed range is 1,000 amps. to 200,000 amps.

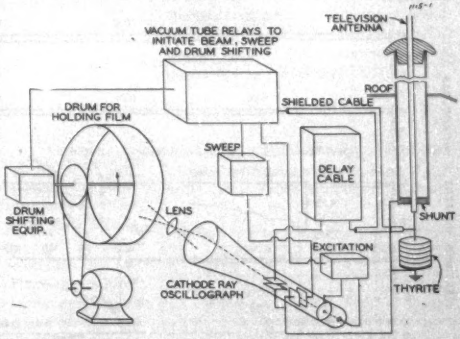

Figure 1. Schematic diagram of high-speed cathode-ray oscillograph equipment used for lightning investigation in the Empire State Building, New York City

Camera equipment is located at 500 Fifth Ave. a distance of 2,550 ft. to the top of the Empire State Building. Slow speed ($^1/_8$ rps) and (2 rps) Boys cameras are installed and also a high speed Boys camera normally having a film surface velocity of 124 ft. per sec. In addition, a moving film camera called a "multiple aperture camera" is used having four matched lenses so arranged that four images appear on the same moving photographic film along a horizontal axis. The lenses are provided with suitable filters and stop openings, so that a range of about one million to one may be obtained in exposure.

In addition to this equipment, another camera referred to as the "oblique camera" was installed on a building at the corner of 34th St. and 8th Ave. The purpose of this camera is to determine the shape of the stroke in a plane at right angles to that of the cameras at 500 Fifth Ave. so that a more accurate determination of the length of the stroke path might be made. This camera, controlled over a telephone circuit by the operator at 500 Fifth Ave., is not a Boys camera; its only purpose being to get the stroke shape, and no attempt is made to record detailed time effects.

A densitometer has been provided in the laboratory at Pittsfield for the study of changes in density found on the photographic records. All of the films used since the study began in 1935 have been provided with a sensitometer strip for calibration of the film against a known light source.

Means were set up in 1940 for the determination of visibility between 500 Fifth Ave. and the Empire State Building. This instrument was provided to make possible a fair determination of current from the Boys camera photographs, and studies are in progress to determine the change in current as one progresses up the

Paper 41-115, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 11, 1941; made available for preprinting May 9, 1941.

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The author wishes to express his appreciation to the high voltage engineering laboratory staff at Pittsfield, particularly to J. H. Hagenguth, J. W. Flowers, John Russ, and Paul Edwards in connection with designing and operating the equipment, and to Harry Mason for assistance in the preparation of the material used.

1. For all numbered references, see list at end of paper.

stroke—thus obtaining some data on the space charge around the stroke channel.

Brief Résumé of Results Previously Reported[1,2,6]

Some of the more important results obtained in this study, particularly with the camera equipment, are listed briefly below. Only oscillographic data are discussed in the present paper.

1. Discovery of the initial upward step leader mechanism from the Empire State Building.

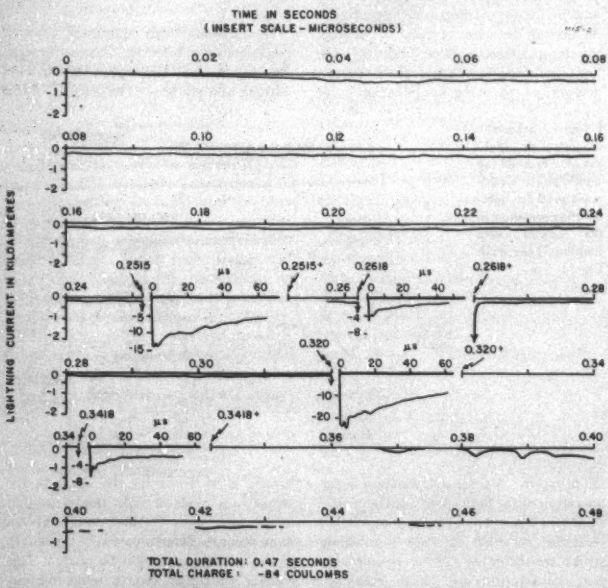

Figure 2. Composite replotted from low-speed and high-speed oscillograms showing our current peaks of stroke 3 to the Empire State Building

June 26, 1940 at 1:29.5 p.m.

2. Proof, both photographic and oscillographic of the existence of continuing current (substantially a direct current arc between line and ground).
3. Direct measure of charge in coulombs in lightning strokes, establishing a curve of frequency of occurrence for a given magnitude.
4. Oscillographic records show that out of 27 records all began with negative polarity, and 3 reversed polarity at end of the record, indicating that the base of the cloud is negative, and a positive region was reached in 3 cases only after a time interval.
5. Lack of so-called return stroke from clouds with upward initial leader mechanism, explained by lack of mobility of charges in clouds compared to the earth, which does produce a return stroke with downward initial leaders.
6. Strokes to ground, whether started by upward or downward initial leader, seem to have same mechanism for successive current peaks without reference to how initiated.
7. The configuration of electrodes probably determines the direction of propagation of initial leader.
8. Thunderless lightning results from relatively slow rates of current rise of upward leader strokes, without successive current peaks.
9. Measurement of leader and stroke propagation velocities and approximate determination of current required by upward step leader.
10. Identification of the upward streamer from earth when the downward initial leader approaches the earth.
11. Determination of wave shape of direct strokes—front, crest, and duration of current peaks of strokes having single peaks and as many as 12 successive current peaks (total of 4 strokes recorded).
12. Strokes to the ordinary countryside, in those cases where the photography was such that good measurements could be made, show the same general photographic characteristics as do those to the Empire State Building, once the stroke is established.

Additional Results

Considerable additional data obtained in 1940 are now available with respect to the wave shape of current peaks. Although many correlating oscillograms and photographs were obtained in previous years, during 1940 most of the strokes were not recorded photographically because they did not occur at night. It is believed, however, based on past experience that most of the strokes recorded were initiated by upward step leaders.

During the 1940 season the low speed oscillograph recorded 17 of the 20 strokes to the building, while the high speed oscillograph recorded 41 current peaks in 13 strokes. The correlation between the low and high speed oscillograms was excellent, there being a detailed record of nearly every current peak of any importance appearing on the low speed record. Such a record for stroke 3 (1940) is shown in figure 2, where the high speed and low speed records have been reproduced together.

Polarity

Of the 49 strokes recorded oscillographically during the years 1937–40, no stroke has been entirely positive although 41, or 84 per cent, were entirely negative. Of the eight strokes having some positive, one is known to have begun with a small positive current (about 200 amps), while four strokes began with negative current. With two other strokes, the current recorded initially appeared to be negative, but had too small a magnitude to be certain. As for the remaining stroke, the first current recorded was positive, although the oscillograph had initiated more than 0.025 sec. before indicating the presence of a current, whose magnitude and polarity is, however, unknown. This stroke (No. 13, 1940) is of considerable interest, as the first recorded current was a positive peak having a crest of 58,000 amps., which is nearly double the highest heretofore recorded oscillographically[4] to the building. This was followed by three negative current peaks, as shown in figure 3. The current peaks appear to be connected together by continuing current, mostly negative.

Stroke Charge

The stroke charge in the entire stroke including current peaks for 49 strokes is given in figure 4, and indicates that at least 50 per cent of strokes have a charge of 25 coulombs or more, although the average charge is 37 coulombs. The maximum measured in New York is 164 coulombs obtained in 1937, while in 1940 the maximum was 150. Three per cent of the total charge measured to date was positive.

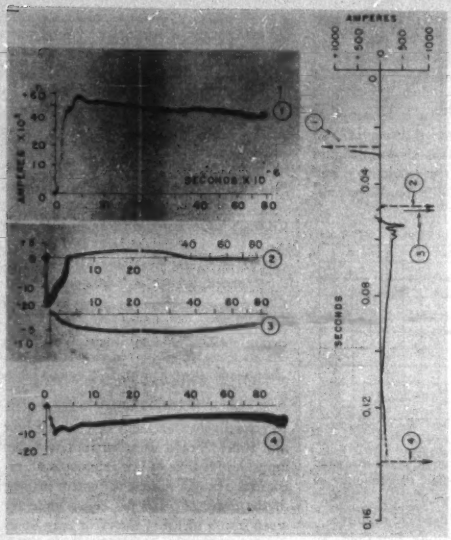

Figure 3. Low-speed and high-speed oscillograms showing four current peaks of stroke 13 to the Empire State Building

June 30, 1940 at 4:34 p.m. Time between peaks 0.021, 0.00092, and 0.087 second

Continuing Strokes

Of the 49 strokes recorded oscillographically, only seven did not show any signs of continuing current, and these due to lack of sensitivity might have recorded current under more favorable recording conditions. Of these oscillographic records 20 correlating Boys camera records were obtained—all but one showing the presence of continuing current. In addition to these photographic records 42 others were obtained—41 of which show the presence of continuing current. Thus 91 per cent of all strokes recorded in New York to the Empire State Building are classified as continuing.

It is of interest to record here that the results obtained thus far with the multiple aperture camera indicate that once a path is found between cloud and ground the current does not cease until the stroke is completed. The current merely increases and decreases in magnitude until the total stroke is completed.

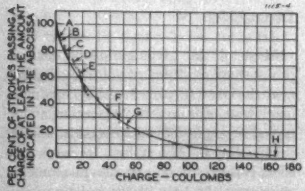

Figure 4. Frequency of occurrence of stroke charge based largely on low-speed oscillographic data

Total charge of lightning strokes recorded by low-speed oscillographs

Empire State Building, New York City
1937, 1938, 1939, 1940

Based on 49 strokes

Coulombs in two-polarity strokes

	A	B	C	D	E	F	G	H
−1.4	2.0	5.4	12	8.2	30	36	160	
+1.2	1.1	1.8	2.3	9.9	17	17	2.6	

Other strokes negative charge only

Stroke Duration

The maximum stroke duration of 1.5 sec. reported in 1937 for a stroke to the building has not as yet been exceeded. Figure 5 shows that half of the 49 strokes recorded have a duration of at least 0.29 sec.

Current Peaks—Crest Current

The data given in figure 6 are plotted in terms of negative current peaks, since all the peaks recorded by the high speed oscillograph were negative but one, which is indicated. When comparing these data with those of other investigators, it is to be remembered that the magnetic link used in measuring currents through transmission towers[2] and distribution lightning arresters[3] indicate only the highest current peak occurring during the time the link is in service. In figure 6 each current peak in a stroke is plotted independently. It is not strange that Lewis and Foust give current values considerably higher than indicated in figure 6. The data given by McEachron and McMorris for distribution circuits are much lower in current magnitude, since the current was measured only at arrester locations, and in most cases is a measure of the traveling wave from some remote point. In many cases, too, the measured surge was the result of the release of a bound charge. The records do indicate arrester duty, but seldom the current magnitude in the stroke itself.

Duration

In terms of time to half value only 25 per cent of the 33 peaks measured in 11 strokes have a duration exceeding 40 microseconds, which is the present standard duration used in impulse testing in the United States. The maximum duration (figure 7) was 115 microseconds.

Charge

Since the tail of the current peak merges into the continuing current it is difficult to determine what is the current peak and what is continuing current. Therefore, when determining the charge in each current peak the area under the current-time oscillogram has been limited to the point where the current has decayed to half value. Figure 8 shows that 50 per cent of the current peaks measured have a charge of 0.13 coulomb or more, although only 5 per cent showed more than 1.5 coulombs.

Since the cloud is not an infinite bus but has limited energy, one might expect that as the current increased the duration might decrease, but figure 9 indicates that

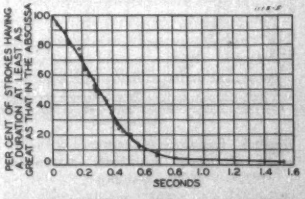

Figure 5. Stroke duration as a function of the frequency of occurrence

Values obtained from oscillographic records

Duration of multiple and continuing lightning strokes recorded by low-speed oscillographs

Empire State Building, New York City
1937, 1938, 1939, 1940

Based on 49 strokes

the charge is increasing more rapidly than the current, which means of course that the duration is also increasing with the current. If the rate of propagation of the so-called return stroke is independent of the current in the stroke, and if the duration of the tail of the current peak is the time taken to reach the cloud, it would appear then that in general the longer stroke path will contain the greater current. There is yet no real support for either of these assumptions, nor is there any direct measure of the length of the stroke path compared to its current. Furthermore, large and small current peaks are recorded in the same stroke, apparently indicating the presence of other factors beside the length of stroke which may influence the amount of current. While ground resistance may have considerable influence on the amount of current, yet it must be remembered that all of the current peaks recorded in figures 6 or 9, occurred to a structure whose ground

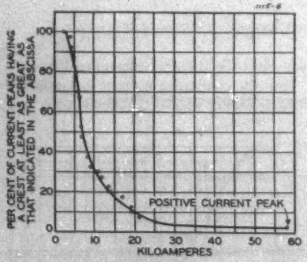
PER CENT OF CURRENT PEAKS HAVING A VALUE AT LEAST AS GREAT AS THAT INDICATED IN THE ABSCISSA
POSITIVE CURRENT PEAK
KILOAMPERES

Figure 6. Frequency of occurrence of current peaks of various magnitudes determined oscillographically

Amplitude of current peaks recorded by high-speed cathode-ray oscillograph

Empire State Building, New York City

Based on 13 strokes

resistance was presumably quite constant —certainly it did not change during a stroke.

Wave Front

The time to the first crest is given in figure 10. These results show that a time of at least one microsecond is required to reach crest in 50 per cent of the peaks. Sixty-five per cent of the current peaks reach the first crest in a time of not more than 1.5 microseconds, the present standard time. It was of interest to plot the time to first crest against the crest value of current, but no trend could be found, except that higher currents usually required longer times to reach crest, but longer times did not necessarily mean a higher current peak.

Rate of Rise

The effective rate of rise in kiloamperes per microsecond, measured through the 10 and 90 per cent points is shown in figure 11. In considering these results it is well to bear in mind the difficulties encoun-

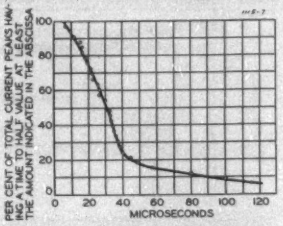

Figure 7. Duration of current peaks measured to half value as a function of frequency of occurrence

Based on 33 oscillographic records

Duration of current peaks recorded by high-speed cathode-ray oscillograph

Empire State Building, New York City 1938 and 1939

Based on 11 strokes

tered in recording and measuring accurately when the front becomes almost perpendicular to the time axis. It is clear that as the rate of rise increases the possibility of error increases, and therefore the highest values in figure 11 are to be taken with caution, since an error of the order of ±50 per cent may be present.

These results do indicate that rates of current rise of the order of 10 to 20 kiloamperes per microsecond will be encountered quite frequently in the stroke, and values as high as 30 to 40 kiloamperes occasionally. These values are to be compared with those of Norinder,[8] which are of the same general order of magnitude although obtained in Sweden by quite a different method.

Accuracy of Measurement

Measurement of the crest of the average current peak (9,000 amp.) is subject to an error of ±20 per cent. The major factors contributing to this error are difficulty in establishing a zero line, uncertainties in the measurement of deflections and in the value used for the oscillograph calibration including the lightning shunt. For smaller deflections, the error tends to be greater and may be less for the larger deflections.

Rate of rise measurements are subject

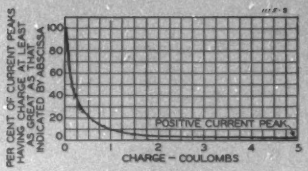
PER CENT OF CURRENT PEAKS HAVING CHARGE AT LEAST AS GREAT AS THAT INDICATED BY ABSCISSA
POSITIVE CURRENT PEAK
CHARGE – COULOMBS

Figure 8. Charge of current peaks as a function of frequency of occurrence

Coulomb values based on time to half value of crest current

Charge in current peaks recorded by high-speed cathode-ray oscillograph

Charge passed until current decays to one-half of crest

Empire State Building, New York City 1938 and 1940

Based on 13 strokes

to error in measurement of both current and time. For a crest current of 9,000 amps. and a time of one microsecond, error in the rate of rise measurement may be of the order of ±25 per cent, while for steep fronts (0.1 ms) the error may be as great as ±50 per cent.

Measurements of charge are also subject to a possible error of ±25 per cent.

The low speed oscillograms are also subject to a possible ±20 per cent error in current magnitude; while currents smaller than 50 amps. are detectable, the accuracy is very poor, since the trace is often about 150 amps. in width.

It is believed, however, with the exception of the measurements depending upon fractional parts of microseconds, that the average accuracy is good for this type of measurement.

Discussion

Most of the oscillograms of current peaks show evidence of some oscillation near the crest (figures 2 and 3), having a magnitude of from 5 to 20 per cent and a period of about 2.5 microseconds. Since the building is 1,275 ft. high, perhaps this effect is the result of reflection phenomena at or near the base of the building. Of course the size of the building increases near the earth, which confuses the picture somewhat.

In applying these results to the case of lightning striking a transmission or distribution circuit, several assumptions must be made. It seems reasonable to assume that the sum of the currents flowing away from the point of contact with the lightning stroke will equal the current of the stroke, in view of what is now known of the mechanism of the stroke. Thus, if a line is struck at any point except close to

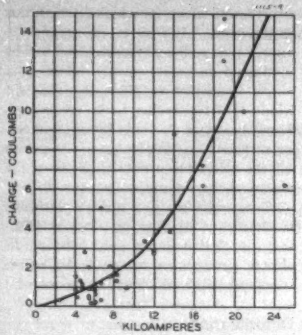

Figure 9. Effect of variation in crest current on the charge contained in each current peak

Relation between charge and crest current of negative current peaks

Charge passed until current decays to one-half of crest

Empire State Building, New York City
1938 and 1940

Based on 13 strokes

Charge of only positive peak recorded was 4.9 coulombs with crest of 58,000 amperes

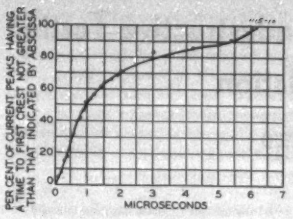

Figure 10. Time to first crest of current peaks as a function of frequency of occurrence

Recorded by high-speed cathode-ray oscillograph

Empire State Building, New York City
1938 and 1940

Based on 13 strokes

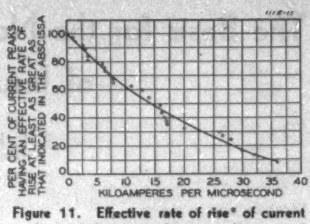
PER CENT OF CURRENT PEAKS HAVING AN EFFECTIVE RATE OF RISE NOT LESS THAN THAT INDICATED IN THE ABSCISSA
KILOAMPERES PER MICROSECOND

Figure 11. Effective rate of rise* of current peaks of lightning strokes as a function of frequency of occurrence

Recorded by high-speed cathode-ray oscillograph

* Slope of line through points on wave front at 10 per cent and 90 per cent of first crest

Empire State Building, New York City
1938 and 1940

Based on 11 strokes

its end, the current in the stroke will divide equally and will have half of the magnitude of the original measured stroke current. The time to crest and half value will be the same as measured in the stroke itself, thus the rate of rise in terms of amperes per microsecond would be reduced to half that found in this investigation of strokes to a well grounded steel structure.

Current waves traveling away from the point struck are associated with a traveling wave of potential equal to the surge impedance multiplied by the current. Thus stroke 13, figure 3, having a crest current of 58,000 amps., the highest yet measured oscillographically, would have a traveling wave current of 29,000 amps. This corresponds to a traveling wave potential of 14,500,000 volts (using a surge impedance of 500 Ω) which would flashover any insulation now in use, either wood or porcelain. If, however, the stroke made contact with an overhead ground wire at a tower having a ground resistance of 10 ohms, the potential at the tower top would be only 580,000 volts, neglecting the current flowing away from the stricken point which would be only a little over 2,000 amps. until reflections from adjacent towers returned to increase the current.

Thus the data obtained may be applied to transmission line conditions with reasonable accuracy. If the stroke is considered to have struck a considerable distance away from the ends of the line, then the traveling waves will contain a current half that shown in figure 6 and also a coulomb value of half that given in figure 8. If the stroke is at or very near the end of the line (within a few hundred feet) the traveling wave currents and corresponding voltages will be as originally given.

The wave shapes to reach apparatus will depend upon the point struck with reference to the apparatus, the insulation levels, surge impedance, coupling, and other factors. If overhead ground wires are used and the stroke does not initially make contact with the line conductors, the disturbance will be essentially local, if tower footing resistance is low enough and the line insulation high enough.

The total stroke consists not only of current peaks but also of long time low values of continuing current.

In the case of the transmission line, if the ground wire is struck these continuing currents find their way directly to ground. If the current peak was not of sufficient magnitude to cause flashover, the continuing current will not be of any importance, except for some burning of the ground wire which may result since this current is of the nature of a direct current arc.

If a continuing stroke causes an insulator flashover, the presence of the continuing current following arcover may interfere with the operation of the automatic reclosing equipment, if the latter is sufficiently rapid. Such continuing current in the conductors due to a stroke will be carried to ground through neutrals of transformers if grounded, while if the system neutral is isolated lightning arresters may be forced to carry such currents, which might possibly result in damage to the arrester, although in general the failures of arresters have been very small, indicating that currents of this character do not occur very frequently.

In the case of distribution circuits, often several paths to ground exist over guy wires, through lightning arresters, and in the case of grounded neutrals continuing currents will find their way through many multiple paths to ground without undue duty on the lightning arresters. No doubt the continuing type of discharge is responsible for some of the fuses blown during lightning storms.

When using direct stroke data, such as given in this paper, to determine what may happen on either distribution or transmission circuits, proper consideration should be given to circuit conditions. Seldom, if ever, can direct stroke values be used directly.

It is also important to point out that there is good reason to believe that ground resistance will have an appreciable effect[1] on the current in a lightning stroke—the lower the resistance the higher the current, other factors being equal. The effect of ground resistance on wave fronts of direct strokes is not known, but one would expect that higher ground resistance would probably effect some increase in the duration of the stroke, although the effect of the cloud distribution of charge is probably controlling.[1]

Conclusion

For the first time, sufficient data relative to wave shapes of direct strokes are available to make possible the drawing of experience curves with respect to front, crest, and tail of current peaks. Similar data with reference to the total stroke are also available.

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1. Lightning to the Empire State Building, K. B. McEachron, *Journal* of Franklin Institute, volume 227, 1939, pages 149–217.

The Basis for the Nondestructive Testing of Insulation

R. F. FIELD
MEMBER AIEE

Introduction

DIELECTRIC strength is the property of insulation that is most important to the operating power companies. The factor of safety determined by the ratio of breakdown voltage to operating voltage must be maintained. Yet this breakdown voltage cannot be measured on a finished piece of insulation. Actual breakdown, except in the case of liquids, destroys the insulation. Overvoltage less than that required for breakdown has been found to injure the insulation and leave it with a reduced factor of safety. Non-destructive testing at overvoltage is feasible only if some electrical quantity, such as current, is measured and used as a sensitive indicator of incipient damage. The use of d-c overvoltage from a tube rectifier for cable testing is an example.

Non-destructive testing of insulation, as currently practiced, is the measurement of certain electrical characteristics of the insulation, such as capacitance, dissipation factor,* and leakage resistance, at a voltage not greater than the operating voltage. Ordinarily a relatively low voltage at the operating frequency is used, 100 volts to 10 kilovolts. Of these three characteristics, dissipation factor has come to be considered the most reliable indicator of the condition of insulation. The standard practice is to measure the dissipation factor of insulation at the operating frequency at stated intervals of time after installation. A progressive increase of dissipation factor with time is believed to indicate deterioration of the insulation. Certain limiting values are set depending on the type of insulation. When these limits are exceeded, the insulation is removed from service. Frequently, greater weight is placed upon continual change in the value of dissipation factor than upon its absolute magnitude.

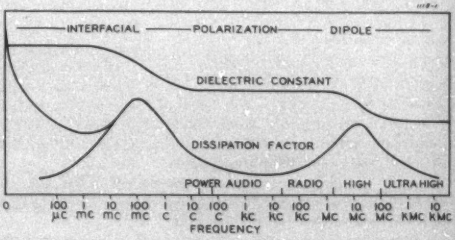

Figure 1. Schematic diagram showing changes in dielectric constant and dissipation factor with frequency (after Murphy and Morgan)

The upper branch of the dissipation factor curve shows the effect of d-c conductivity

Heretofore the assumption has been made that, when insulation deteriorates, a correlation exists between the decrease in dielectric strength and changes in dissipation factor, because the use of nondestructive testing has resulted in a decrease of insulation failures. It is, however, a fact that the greatest success has been attained with the simpler types of bushings and insulators, only fair success with transformers, and little success with generators and cables. This is probably true because the changes in dielectric strength on the one hand and in the three measurable electrical quantities on the other are all effects for which deterioration is the cause. It is also unreasonable to expect that sufficient information will be contained in measurments taken at a single frequency to allow the different kinds of deterioration to be recognized. It will be shown that only by taking measurements over a wide frequency range can all the information obtainable from the electrical characteristics be secured.

These considerations make it desirable to determine whether or not a satisfactory correlation should exist between dielectric strength and one or all of the electrical quantities which can be measured.

Deterioration

The many causes of deterioration occuring in insulation may be grouped under four heads, chemical, mechanical, and electrical changes and the introduction of foreign material. The processing of many commercial dielectrics is incomplete. Either polymerization is not complete or the solvents are not completely volatilized. During the subsequent changes, voids may form throughout the body of the material. Voids are also formed in laminated materials under the vibrational and mechanical forces to which insulation is subjected in rotating machines and in transformers.

Foreign materials, mainly dirt and moisture, may adhere to the surface of insulation or may penetrate throughout the volume, if the body is porous. This is not usually an irreversible change. Cleaning and heating will usually restore the original properties, but, as long as the foreign material is present, dielectric strength may be impaired.

The existence of voids and the presence of foreign material offer the possibility of ionization, even at operating voltage. The surface of the voids will eventually carbonize and add a semi-conducting path. On the outer surface of an insulator this produces tracking. Permanent damage is done in either case.

Paper 41-118, recommended by the AIEE committee on electrical machinery, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16-20, 1941. Manuscript submitted December 5, 1940; made available for preprinting May 12, 1941.

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1. For all numbered references, see list at end of paper.

* Dissipation factor is the cotangent of the phase angle, while power factor is the cosine.

2. Playing With Lightning, K. B. McEachron and K. G. Patrick, 1940.

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6. Wave Shapes of Successive Lightning Current Peaks, K. B. McEachron. *Electrical World*, volume 113, 1940, number 6, page 428.

7. Lightning Investigation on Transmission Lines—VII, W. W. Lewis and C. M. Foust. AIEE Transactions, volume 59, 1940 (April section), pages 227–32.

8. Discharge Currents in Distribution Arresters—II, K. B. McEachron and W. A. McMorris. AIEE Transactions, volume 57, 1938 (June section), pages 307–12.

9. Lightning Currents and Their Variations, H. Norinder. *Journal* of Franklin Institute, volume 220, 1935, number 1, pages 69–92.

Of these various kinds of deterioration the formation of voids and the absorption of moisture are most common.

Mechanism of Breakdown

Breakdown in solids has been studied extensively by von Hippel[1] and others. The application of a voltage produces a motion of free electrons and free ions toward the electrodes. If sufficiently long free paths exist, enough velocity is attained by these carriers of electricity to produce other ions by collision. As long as the motion of the carriers is limited, as by cleavage planes in crystals and by interfaces in mixtures, the insulation is stable. However, when the ionization becomes sufficiently intense, enough carriers are formed to blast an irregular path between the electrodes. This is breakdown.

Whatever increases the supply of free electrons and ions or lengthens their mean free paths lowers the breakdown voltage. This suggests that there may be a good correlation between dielectric strength and d-c conductivity.

Polarization

The values of dielectric constant and dissipation factor obtaining in insulation at any one frequency, or over a range of frequencies, are determined by the existing polarization. A value of dielectric constant greater than unity indicates polarization and an extra contribution to capacitance from polar groups. At optical frequencies a value of the refractive index greater than unity shows that some polarization exists. Any value of dielectric constant greater than the square of the refractive index indicates further polarization. A plot of dielectric constant against frequency has the general shape indicated in figure 1, which is after Murphy and Morgan.[2] The greatest value of dielectric constant occurs at zero frequency.

Two general types of polarization occur over the audio- and radio-frequency range, dipole and interfacial. The former was suggested by Debye and the latter by Maxwell, later amplified by Wagner. Dipole polarization is produced by polar molecules, in which the electrical centers of the positive and negative charges do not coincide. In an alternating electric field, such dipoles attempt to follow the direction of the field. At sufficiently low frequencies there is time enough during each half cycle for nearly all of the dipoles to place themselves in line with the field and that type of polarization is complete. The time required to carry the polarization to $1-1/e$ or 0.632 of completion is called the relaxation time. The corresponding frequency for which the polarization is complete usually appears in the megacycle range for the simpler polar molecules. For the more complex chain molecules, where dipoles occurring along the chain may produce a torsional vibration, this frequency may be found in the audio range.

The rotational motion of the dipoles is opposed by their own heat motion and the motion of the other molecules, with the result that a definite amount of energy is lost at each cycle. The power loss at any frequency is the product of the energy loss per cycle and the frequency. It decreases to zero at both zero and infinite frequencies and hence produces a maximum in dissipation factor at some intermediate frequency.

The d-c conductivity also contributes to the dissipation factor at very low frequencies and causes the numerical value of dissipation factor to become infinite rather than zero at zero frequency. This effect of d-c conductivity at very low frequencies is shown in figure 1, by the upper branch of the dissipation factor curve. For all ordinary dielectrics this contribution to dissipation factor is negligible at audio frequencies.

Interfacial polarization occurs at the interfaces of dissimilar dielectrics. These interfaces can occur as a few large surfaces between two materials or as innumerable small surfaces produced by finely divided particles. The free electrons and ions move throughout the volume of each dielectric and heap up at the interfaces. The charge accumulated at the interfaces during each half cycle contributes to the polarization in exactly the same way as does the lining up of the dipoles in dipole polarization. The resultant changes with frequency in dielectric constant and dissipation factor follow identical laws. In fact, it is not possible to distinguish the two types of polarization from the shapes of their frequency curves.

A condition necessary for the existence of interfacial polarization is an inequality in the product of dielectric constant and specific resistivity for the two dielectrics. This dependence of interfacial polarization on resistivity, and hence on free electrons and ions, suggests that there may be a good correlation between dielectric strength and the dissipation factor resulting from interfacial polarization.

Single Relaxation Time

For a polarization having a single relaxation time the changes of the various

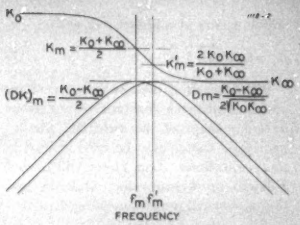


Figure 2. Change of dielectric constant, loss factor, and dissipation factor with frequency for a single-relaxation-time polarization

electrical characteristics with frequency follow definite laws. The polarization is completely defined[3] by the high-frequency dielectric constant K_∞, the low-frequency dielectric constant K_0 resulting from complete polarization and the relaxation time T. The maximum value of loss factor* is

$$(DK)_m = \frac{K_0 - K_\infty}{2} \tag{1}$$

and occurs at a frequency

$$f_m = \frac{1}{2\pi T} \tag{2}$$

which may be called the relaxation frequency. The curve of loss factor is symmetrical about the relaxation frequency and is expressed by

$$\frac{(DK)}{(DK)_m} = 2\,\frac{f/f_m}{1+f^2/f_m^2} \tag{3}$$

where both loss factor and frequency have been normalized with respect to their values at the relaxation frequency.

The curve of dielectric constant also has a kind of symmetry about the relaxation frequency and is expressed by

$$K = K_\infty + \frac{K_0 - K_\infty}{1+f^2/f_m^2} \tag{4}$$

The value of dielectric constant at the relaxation frequency is the average value.

$$K_m = \frac{K_0 + K_\infty}{2} \tag{5}$$

The shapes of these curves are shown in figure 2, where frequency and loss factor are plotted logarithmically while dielectric constant is plotted arithmetically. The curve of dissipation factor is also plotted logarithmically in figure 2. In its normalized form the expression for dissipation factor is identical with equation 3 for loss factor, with a maximum value

$$D_m' = \frac{K_0 - K_\infty}{2\sqrt{K_0 K_\infty}} \tag{6}$$

*Loss factor is the product of dissipation factor and dielectric constant.

which occurs at a higher frequency

$$f_m' = f_m\sqrt{K_s/K_\infty} \qquad (7)$$

Whenever it is inconvenient to obtain values of dielectric constant because of the irregular shape of the dielectric, the capacitance values may be used instead in these equations. Loss factor will have a different numerical value, while dissipation factor will remain unchanged.

Multiple Relaxation Times

The curves obtained for the various dielectrics and for commercial insulation have very much broader maxima than the curve for a single relaxation time shown in figure 2. In addition, the value of maximum loss factor is much less than that calculated from equation 1. The explanation given by Wagner and amplified by Yager[4] is that there exists a group of relaxation times distributed according to some probability law.

The curves shown in figure 3 are given by Yager[5] for a paper base phenolic, curves 15*D* for a dry specimen and curves 15*H* for the same specimen conditioned at 60% relative humidity. The maximum in loss factor at a frequency of ten megacycles is produced by dipole polarization of the cellulose filler and the curve is much broader than that shown in figure 2. The slight rise appearing at audio frequencies in curve 15*D* and caused by interfacial polarization is greatly increased by the moisture added under the conditions of curve 15*H*. The relaxation frequency of this polarization is well below the audio-frequency range. This curve is so broad that loss factor is increased even at ten megacycles.

Circle Diagrams

Cole and Cole[6] have recently offered a simpler and more fruitful explanation for the broad maxima. The properties of a polarization having a single relaxation time are such that a plot of loss factor and dielectric constant, as shown in figure 4*a*, is a semicircle with its center on the dielectric constant axis and with intercepts on this axis equal to the zero and infinite frequency dielectric constants. It becomes apparent immediately that the maximum loss factor must be one-half the change in dielectric constant as stated in equation 1.

The important discovery of the Coles is that when loss factor is plotted against dielectric constant for various insulating materials a circular arc results whose center is depressed below the dielectric constant axis by an angle ϕ as shown in figure 4*b*. The ratio α of this angle to a right angle is taken as the fourth parameter in defining the polarization. It can be considered as a storage coefficient, which determines the ratio of the stored energy to the dissipated energy for whatever mechanism is assumed for the polarization. The data of figure 3 for a paper base phenolic are thus plotted in figure 5. The circular arc is well defined for the dry material and the divergence of the points at the low frequency end shows the existence of a second polarization. For the wet material the effect of the interfacial polarization is very marked but the data were not carried to low enough frequencies to define its circle. Values of the four parameters for the high frequency polarization are given in table I.

Table I. Paper-Base Phenolic

	K_∞	$K_s - K_\infty$	f_m Mc	α
15*D*	3.76	1.08	14	0.52
15*H*	4.01	2.72	20	0.63

The addition of moisture, while slightly increasing the storage coefficient δ, has its greatest effect on the change in dielectric constant $K_0 - K_\infty$.

Effect of Temperature on Polarization

The effect of increasing temperature on both types of polarization is to decrease the forces opposing the motion of the carriers and thereby to raise the relaxation frequencies. This moves upward on the frequency scale all the curves of dielectric constant and loss factor without greatly changing their numerical values. At a given frequency dielectric constant always increases with temperature at the lower temperatures and consequently its temperature coefficient is positive. The magnitude of this coefficient is by no means constant but depends both upon the amount of polarization and on the ratio of the measuring frequency to the relaxation frequency. After the polarization is complete at a high temperature, dielectric constant frequently decreases and the coefficient becomes negative.

Loss factor and dissipation factor may increase or decrease with temperature depending on whether the measuring frequency is greater or less than the relaxation frequency. For most commercial insulation showing interfacial polarization the relaxation frequency is well below both audio and power frequencies, and the temperature coefficient is positive. It is always possible, however, for polarization from a single interface or from dipoles to occur at a higher frequency than the measuring frequency and make the temperature coefficient negative.

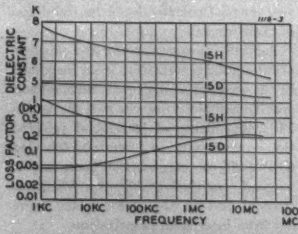


Figure 3. Change of dielectric constant and loss factor with frequency for a paper-base phenolic (after Yager)

15*D* dry, 15*H* conditioned at 60 per cent relative humidity

Effect of Voltage on Polarization

The effect on polarization of increasing voltage is to increase the amount of interfacial polarization because of the increase in the number of free electrons and ions. This will generally increase the value of maximum loss factor and decrease the d-c resistance.

Polarization in Commercial Insulation

Commercial insulation, as used in bushings and insulators, consists of a number of dielectrics in series and parallel. Interfacial polarization, with maximum dissipation factor occurring in the millicycle range,* is usual. Curves of capacitance and dissipation factor for a 25-kv compound-filled bushing are given in figure 6 for four different temperatures. These observations were taken on a Schering bridge operating at 100 volts. The shapes of the curves indicate the existence of both a high-frequency and a low-frequency polarization, but the frequency range is insufficient to allow the construction of circular arcs, even though the lowest frequency used was ten cycles.

The temperature coefficients are all positive and have the values given in table II.

The large variations in temperature coefficient indicate the difficulty of stating a single value applicable under all conditions.

*From 0.001 to 1 cycle per second. A frequency of one millicycle is 0.001 cycle per second.

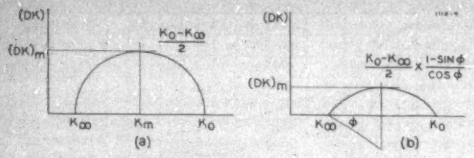


Figure 4. Circle diagrams (after Cole)
(a) Center of circle on dielectric constant axis
(b) Center of circular arc depressed by angle ϕ

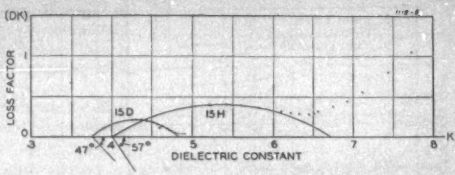


Figure 5. Circle diagrams for paper-base phenolic of figure 3
15*D* dry, 15*H* conditioned at 60 per cent relative humidity

Similar curves for a 66-kv multiple shell porcelain insulator are given in figure 7. Superposed on the low frequency polarization of the porcelain are the polarizations at the interfaces of the porcelain shells and the cement which holds the shells together. The changes in their relaxation frequencies with temperature amount to about 15% per degree centigrade. This is sufficient to cause the dissipation factor curves to cross each other

Table II. Temperature Coefficients for 25-Kv Bushing

f Cycles	C % Per Deg C	D % Per Deg C
10,000	0.24	0.7
1,000	0.25	1.1
120	0.27	3.1
60	0.29	3.8
10	0.48	8.6

and the capacitance curves to be anomalously spaced. The temperature coefficient of dissipation factor changes sign with both temperature and frequency and cannot be used for correcting to a standard temperature. The average temperature coefficient of capacitance at 60 cycles is 0.3% per degree centigrade.

The change in the interfacial polarization of porcelain and cement as the moisture content of the cement is changed is startling. In figure 8 is shown the effect of allowing water to stand in contact with the cement for 5½ hours. The relaxation frequency is raised to 800 cycles. Further soaking for 4 days raises this frequency to 13 kilocycles. Characteristic changes also occur in the capacitance of the insulator. The existence of such polarizations complicates the determination of the main low- and high-frequency polarizations, but affords added information concerning the structure of composite insulation.

Current-Time Curves

The interfacial polarization occurring in commercial insulation has been shown to be of such a nature that its relaxation frequency is well below the range of bridge measurements and in many instances is not greater than a few millicycles. Curves of charging current against time when a voltage is applied, or of discharge current when the voltage is removed, offer a feasible means of measurement. The existence of this charging current has been a great annoyance in the measurement of d-c resistance, and has led to such arbitrary rules as the specification that d-c resistance shall be calculated from the current flowing one minute after the application of the voltage. It is now obvious that resistance calculated in this manner is only an apparent resistance, which actually is a partial measure of the existing polarization. The complete curve contains the information needed to determine all the parameters which define the polarization. Whitehead and Banos[7] in 1932 analyzed charging current curves for paper taken by means of a cathode-ray oscilloscope and obtained values of dissipation factor which agreed within 2% with measurements taken on a 60-cycle Schering bridge. Murphy and Morgan[8] in 1939 placed this method of analysis on a better theoretical basis. They showed that charge and discharge currents differ by the d-c leakage current only when the polarization during charge has been carried to completion. It is necessary either to subtract the leakage current from the charging current before beginning the analysis or to carry the charging to a time which is long compared with the relaxation time before beginning the discharge. It is very difficult to estimate the correct value of leakage current, and the latter method is preferable in spite of the extra time involved.

The charging current at 500 volts for the 66-kv insulator is given in figure 9. After subtracting the leakage current of 0.62 $m\mu a$, the residual current was analyzed into the five exponentials shown, whose relaxation times vary from 0.4 to 63 seconds. The corresponding curves of dissipation factor are shown in figure 10. Their sum is the total dissipation factor

Figure 6. Effect of temperature on capacitance and dissipation factor of a 25-kv compound-filled bushing

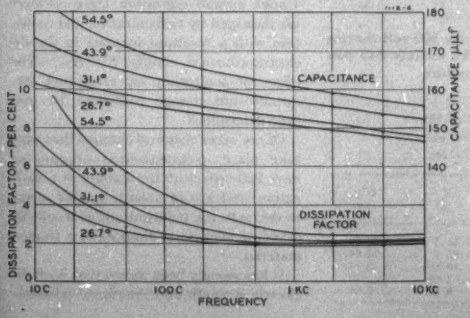
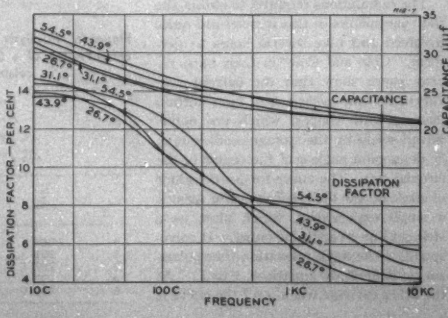


Figure 7. Effect of temperature on capacitance and dissipation factor of a 66-kv multiple-shell, pin-type, porcelain insulator



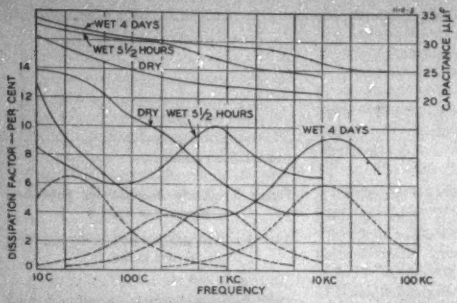


Figure 8. Effect of moisture absorption on capacitance and dissipation factor of a 66-kv multiple-shell porcelain insulator

The contributions to dissipation factor from the polarizations at the cement-porcelain interfaces are shown in dotted lines

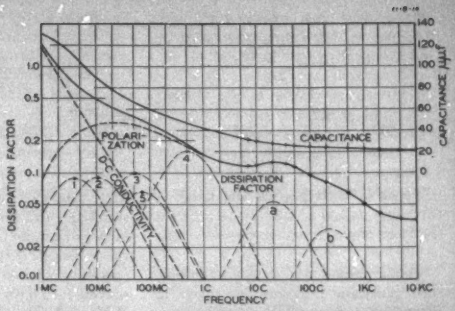


Figure 10. Capacitance and dissipation factor of a 66-kv multiple-shell porcelain insulator as calculated from the exponentials shown in figure 9

produced by the interfacial polarization. The contribution from the leakage current is then added. The corresponding values of capacitance are also given. The resulting circular arc is shown in figure 11. The falling-off of the values of loss factor at the low-frequency end is caused both by the difficulty of estimating the leakage current correctly and by the lack of long time data. The charging current should have been observed for a considerably longer time than 15 minutes. At the high-frequency end the points diverge because of the extra polarizations from the porcelain-cement interfaces. The four parameters derivable from the circular arc are given in the first row of table III.

Table III. 66-Kv Porcelain Insulator

Method	C_∞ μμf	$C_s - C_\infty$ μμf	f_m Mc	α
Exponential	40.2	122.8	.6	0.49
Graphical	115	8	.4	

The calculations required to obtain the four parameters in this manner are quite involved and take several hours to perform. Cole and Cole[3] in their most recent paper show that the current-time curves for any polarization have certain characteristic shapes, which are determined solely by the storage coefficient α, or depression angle ϕ of the center of the circular arc. The curve for $\alpha=0$ (center of circle on the dielectric constant axis) is a single exponential, which plots as a straight line on arith-log paper. It corresponds to the single relaxation-time polarization defined by equations 1 to 7. At the other extreme when $\alpha=1$ the curve is a 45° line when plotted on log-log paper. The family of curves are best plotted logarithmically on both axes. The observed current-time curve, plotted to the same scale, is matched to one of these curves and the values of storage coefficient α, relaxation time T, and current at that relaxation time noted. The residual current curve of figure 9 has been analyzed by this method with the results given in the second row of table III. The agreement between the two methods is reasonably good. It is quite necessary in this graphical analysis to use a discharge-current curve which covers at least three time-decades symmetrically disposed around the relaxation time.

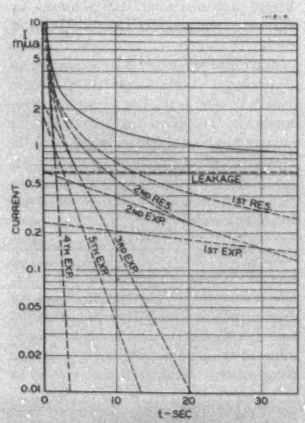


Figure 9. Analysis of the 500-volt charging current curve of a 66-kv multiple-shell porcelain insulator

$E=500v$
$A=806k\Omega$
$C_A=21.1\ \mu\mu f$
$AC_A=17.0$ sec.

	R kMΩ	C μμf	BC_B sec.
1	2,084	30.1	62.6
2	805	25.9	20.84
3	227.2	16.50	3.74
4	33.0	11.62	.38
5	289.0	8.82	2.55

Effect of Deterioration on the Polarization Parameters

The most common types of deterioration in insulation have been shown to be the absorption of moisture and the formation of voids. In a way they go together, because the existence of voids furnishes an additional porosity which can increase the moisture absorption. This appears to be particularly true of the pasted mica insulation used in large generators. The added moisture increases the dielectric-constant change K_s-K_∞ both on account of the high dielectric constant of water and also because of the added interfaces and free ions. The relaxation frequency f_m is usually increased. The effect on the storage coefficient α is not known.

The voids formed by chemical or mechanical means provide additional interfaces at which ionization can occur. Under intense ionization these surfaces are damaged by carbonization and oxidation with a resultant increase in the dielectric-constant change K_s-K_∞. The effect of ionization on relaxation frequency and storage coefficient has not been determined.

Of the other chemical changes that may take place, polymerization appears to have little effect on the amount of polarization, and loss of volatile matter seems to decrease the polarization, as would be expected because of the loss of a foreign material.

It has already been shown that both dielectric strength and interfacial polariza-

tion depend on the abundance of free electrons and ions. The changes in the three parameters K_0-K_∞, f_m, and α will not only measure the amount of the deterioration, but will indicate the type of deterioration as well and hence will suggest the probable decrease in dielectric strength. The success of such interpretation will depend greatly on the thoroughness with which interfacial polarization in typical insulating materials is studied by means of current-time curves.

An important by-product of these studies will be numerical values for the temperature and voltage coefficients of the three parameters. At the present time only their signs are known.[10] The dielectric-constant change K_0-K_∞ decreases slowly with temperature, but increases considerably with voltage. Relaxation frequency f_m increases rapidly with temperature, frequently at the rate of a decade in frequency for a rise of ten degrees centigrade. Storage coefficient α often decreases with temperature. The effect of voltage changes on these two parameters is not yet known. The importance of knowing the temperature coefficients is that it will then be possible to reduce data taken at widely differing temperatures to a standard temperature. Difficulties from rapidly varying coefficients such as were illustrated in figure 6 no longer occur for these polarization parameters.

Single-Frequency Measurements

Only when the kind of deterioration and the type of insulation is known will measurements of capacitance and dissipation factor at a single frequency afford a reliable measure of the amount of deterioration. The relaxation frequency is so low that it makes little difference whether an audio frequency or the power frequency is used. There is no virtue in using the operating frequency and there is considerable advantage in choosing some neighboring frequency, because it will then be much easier to eliminate the effect of the intense electric field at the operating frequency in which many measurements must be made.

Measurements spread throughout the audio-frequency range will add little to the information obtained from single frequency data, except as they may disclose unusual polarizations of the type shown in figures 5 and 6, and as they provide values of the infinite frequency capacitance and dielectric constant. These frequencies will be too far removed from the relaxation frequency to be of any help in constructing a circular arc and thereby determining the polarization parameters. For this same reason even wide changes in the applied voltage will have little effect on capacitance and dissipation factor, even though the changes in zero frequency capacitance C_0 and maximum dissipation factor D_m' are appreciable. Measurements made at the power frequency of 60 cycles on both new and deteriorated bushings at voltages from 50 volts to 10 kv bear out this conclusion.

Conclusions

It has been shown that a satisfactory correlation can exist between dielectric strength and low-frequency interfacial polarization in insulation, because of their mutual dependence on the abundance and disposition of free electrons and ions throughout the material. Any decrease in dielectric strength caused by deterioration can therefore be measured by the corresponding changes occurring in this polarization. The polarization is defined by certain parameters and a new method for their measurement has been outlined, involving the graphical analysis of current-time curves.

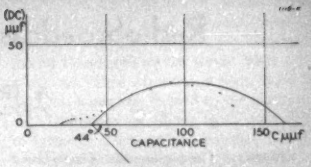


Figure 11. Circle diagram for a 66-kv insulator drawn from the data of figure 10

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Radiobroadcasting in Canada

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ASSOCIATE AIEE

Synopsis: The development of radio broadcasting in Canada has been very rapid and there are now 85 broadcast transmitters in daily operation. All broadcasting is under the control of the Canadian Broadcasting Corporation, an independent Government corporation, which in addition to its regulatory functions operates a coast to coast network connecting together, for a nation-wide service, its own ten modern stations with almost half of the privately owned transmitters. It cannot therefore be said that radio in Canada is owned and operated by the Government as the CBC is independent and free to apply its revenues derived from licenses and commercial operation, in the best interests of its radio audience. The Canadian system is one of co-operation between a semipublic service and private ownership. Parliamentary enquiries have always found it the best suited to Canada's needs considering its vast area and relatively sparse population.

RADIO broadcasting in Canada began at about the end of the last War when an experimental station originated programs for a few hours a day. Following this the first network broadcast in Canada took place on Christmas Day, 1923, when an experimental station in Ottawa was connected to a station in Montreal. In 1926–27 an Eastern Canada network was organized extending from Moncton, N. B. to Toronto; then in 1928–29 our first coast to coast network was inaugurated. Shortly before this time however, on the occasion of the Diamond Jubilee of Confederation, July 1, 1927, Canada's capital city Ottawa was linked for the first time in a nation-wide broadcast using the combined facilities of the Telephone and Telegraph Companies in Canada.

Thus, in 1932, when the Canadian Radio Broadcasting Commission was created by Parliament, the principal wire companies in Canada were already providing facilities for network broadcast. In 1936, the Commission was superseded by the Canadian Broadcasting Corporation which took over the facilities and personnel of its predecessor.

The present system of radio broadcasting in Canada has, since 1928, been considered the best available by all parliamentary committees of enquiry on this subject. Moreover, the present corporation is different from the Commission, which controlled radio from 1933–36, but the principle of accommodating privately owned stations and public service systems has been recognized as the best for Canada for a number of years. The voting in the House of Parliament and of its special committees treating on radio has always been unanimous.

Of the 85 broadcasting stations at present operating on the standard frequency band in Canada, ten are owned and operated by the CBC; the balance are privately owned. Twenty-five of the latter and the ten CBC stations constitute our national network.

The CBC itself is an independent Government corporation, quite free to run its business as it may please, not using public money in any manner but operating with revenues provided by the receiver license fees contributed to the corporation by every owner of a receiving set; this is supplemented by revenues obtained from the commercial operation of the stations. Outside of permitting the corporation to pay for part of the network cost, the national network, commercially run by the corporation, does not bring any appreciable profit.

The CBC is a non-profit enterprise, operating within its own revenues and serving the interests of the public. There are no shares, there are no bonds. The Board of Governors is entrusted with the administration of the revenues placed at its disposal and is responsible for the honest and efficient conduct of the business to a Minister of the Crown. Any surplus in operation is considered as such and invested in the business. It is not distributed as profits and not returned to the public treasury.

On the other hand, privately owned stations operate under conditions similar to those existing in the United States. They conduct their business as they please, and their operating profit is theirs but, as in the United States, they must, pertaining to program only, submit to certain regulations which in Canada are formulated by the CBC.

The restrictions as to program, self-imposed in the case of CBC stations, are such that restraint of private stations is, in my belief, not serious. For instance, the CBC will not carry commercial spot announcements. It will not carry certain types of commercial programs and generally does not accept a great number of the local commercial programs. These restrictions and many others do not apply to privately owned stations.

To emphasize on this freedom of the commercial side of the business, I may state that there are three privately owned stations in Canada which are outlets of the American networks and there are four CBC stations also having direct network connections with American networks. These facts will immediately prove to you that broadcasting in Canada is neither owned nor operated by the Government.

Our dependence on American networks for a good many of our best programs presents some difficulties at times, but generally speaking, it is considered as a very welcome asset and a great means of fostering closer understanding between our two countries.

From the network operating point of view we have problems in Canada which do not exist in the United States. The CBC network, which is the longest east to west network in the world extending over three thousand air miles, covers five time zones instead of the four south of the border. This great distance separating the two extremes of the network and more particularly the great difference in local time renders the problem of co-ordinating the program service very difficult. In addition we have a bilingual population, as almost one third of all Canadians speak French. In the province of Quebec we have besides our basic trans-Canada network a Regional French network. The French speaking minorities located throughout the other eight provinces are however constantly clamoring for more French programs. This presents a problem requiring a good deal of attention. Of course our greatest difficulty in Canada is the same as that faced by our transportation companies and is due to the wide scattering of a relatively small population across an extremely large area. This means low revenue and yet high cost of service. In the United States there is twelve times the population in five-sixths of the area, while in England the British Broadcasting Corporation serves four times the population concentrated in but one sixty-fifth of the area. In normal times this must, at least from the engineering standpoint, be a broadcaster's paradise, where the whole network is hardly longer than some of our local loops and where lines are only a few

Paper 41-113, recommended by the AIEE committee on communication, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 10, 1941; made available for preprinting May 9, 1941.

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hundred miles in length as compared to the five or six thousand miles some programs on this continent have to travel before reaching their destination.

The largest studios are located in Montreal and in Toronto where approximately 50% of our programs are produced. For exchange programs from or to American networks we have special switching facilities at Montreal and Toronto for the National Broadcasting Company Red and Blue networks, at Vancouver and Windsor exchanges with the Columbia Broadcasting System are handled, and again at Windsor for exchanges with the Mutual Broadcasting System and the Michigan Radio network. Broadcasts from the British Broadcasting Corporation in England are relayed to our network through our short-wave receiving station in Ottawa. At this station, we have directional aerials and diversity receivers constantly tuned to various points in Europe and South America. Before hostilities began important features or news gathered in this manner were broadcast over the network. From some of these sources activities are now necessarily curtailed. On the other hand, our relations with the British Broadcasting Corporation are even closer than ever. We have at the present time a number of our men in England working in conjunction with the British Broadcasting Corporation personnel.

One very interesting point is that the CBC is in the enviable position of being able to secure for its listeners, at any time, a greater variety of programs than are normally available to any other broadcasting system in the World. They are made up as follows: First it has access to the leading programs of all the principal networks in the United States. Second, broadcasts from Europe for the time being are limited to those from the British Broadcasting Corporation. Third, its own English network and fourth, its own French network.

Some special feature broadcasts have been of considerable credit to the CBC. An example of this was the Christmas Broadcast in 1935. During the two hour feature pick-ups were scheduled from some 35 different and in some cases almost inaccessible spots ranging from a point two miles under the Atlantic ocean to a golf course on an island in the Pacific. It was during this broadcast that eight choirs located at widely separated cities sang in perfect harmony with an orchestra at another point.

A more recent example involving still wider facilities was the Empire Day broadcast of May 24, 1939, during the visit of Their Majesties. The program which lasted an hour began with a rapid visit across Canada with Canadians speaking from Halifax, Montreal, Toronto, Winnipeg, Regina, Edmonton, and Vancouver then it carried the listener to Africa, Rhodesia, Australia, New Zealand, India, Jamaica, Newfoundland, Scotland, Northern Ireland, Wales, and England and then, to climax the broadcast, back to Winnipeg in Canada for the Empire Day message given by the King himself.

The Canadian contributions were brought together by land lines and those from other points of the Empire via short-wave radio relay lines. In Montreal all these elements were blended into a program which was relayed to 54 stations across Canada and 335 transmitters of the NBC, CBS, MBS, MRN in the United States and also to all parts of the British Empire by means of short-wave radio.

In all, we estimate that over 25,000 miles of telephone circuits and 100,000 miles of radio telephone links were used plus the services of some 2,000 technicians simultaneously engaged at the controls, constituting a program which was within the reach of millions of people.

Summing up, the CBC is mainly concerned with national and regional problems of broadcasting. This explains why it maintains a very elaborate network of broadcasting lines of a total length of over 7,000 miles reaching almost every broadcasting station in Canada. As a matter of fact, these lines are owned and operated for the CBC by our two main railway companies: the Canadian Pacific Railway and the Canadian National Railways. Under contract, the telegraph divisions of these two companies must maintain the wire line service between some 70 points across the country, the service being subject to certain specifications concerning the quality of transmission. This network permits the CBC to reach over 90% of the population of Canada within the primary coverage of some broadcasting station, that is within the 5 millivolts per meter contour of some station. If we consider that people living outside of these areas are for the most part isolated from industrial centers and can therefore obtain good reception from much lower field intensities, it may be said that the CBC network reaches practically all the population of Canada.

For commercial purposes, a group of stations has been organized as a network under the name of the National Network. This is composed of five regional networks which may be handled separately from a commercial point of view. Whenever some program of great national importance is handled by the CBC, for instance for all broadcasts of the Royal Visit or when our Prime Minister or your President has a message to send to the public, such broadcasts are offered to all stations in Canada. Those on the National Network carry the program, the others, while they are not obliged to, usually carry it of their own accord. This, I believe gives you a general outline of broadcasting in Canada.

It is difficult to give correct figures on privately owned stations as they are quite independent to run their show as they please and they are not required to submit a report on their financial operations except, of course, in so far as taxes or revenues are concerned, but files on these matters are not open to the public.

As I have said before, the CBC operates under a budget covering each fiscal year. Since its organization on the 1st of November 1936, the corporation has had a total operating surplus of $1,000,000—$600,000 of which has been re-invested in the corporation's plant. Our board is proud to have been able to operate a rather difficult business with a surplus each year. This is not always the case with organizations who may hope to obtain the help of the Government when they get into bad straights.

During less than five years since its inception, the CBC has built four 50-kw transmitters, one of 5 kw, a $7\frac{1}{2}$-kw short-wave transmitter, and new studios at two points. Besides this, a 5-kw transmitter was revamped as were two sets of studios. It also had the privilege of leasing from the Manitoba Telephone System the studios built by that organization in Winnipeg.

The Engineering Division is divided into five departments:

The Operation Department,
The Transmission & Development Department,
The Architectural Department,
The Design & Construction Department,
and the Purchasing & Stores Department.

Of a total staff of some 600 we have at present 185 employees in the main divisions of the technical service. Forty of these are graduate engineers and 100 are technicians and operators specialized in radio work.

Had it not been for the war we would probably have two important new buildings, one in Toronto and one in Montreal, to take care of our studio and office requirements at those points. The war has prevented heavy capital expenditures.

Although we ourselves fabricate a num-

Development in Lightning Protection of Stations

E. R. WHITEHEAD
MEMBER AIEE

Introduction

THE AIEE transformer sub-committee has recently sponsored a paper[1] on the protection of power transformers against lightning surges. The most effective method given combines overhead ground wires, line entrance gaps, and transformer mounted lightning arresters. Such a method does give a high degree of protection, but it is primarily applicable to high voltage, high capacity stations where the overhead ground wire system is justified for both line and station.

The conditions noted above are seldom fulfilled on subtransmission systems from 23 kv to 34.5 kv. Effective ground wires and low ground resistances are uneconomical, and the protection provided is usually a more or less modern arrester, not always located and grounded to the best advantage.

On the 23-kv subtransmission system of the Duquesne Light Company, the average transmission distance is approximately two miles. This means that most direct strokes will contact the line not more than one mile from some substation. Much of this transmission is now equipped with wood cross arm braces and guy insulators, and at some stations several spans adjacent thereto are carried on unguyed poles.

Under such conditions, it is possible for very high voltage waves to strike the station and result in arrester discharge currents having high rates of rise.

It is the purpose of this paper to outline briefly some of the field experience pointing to this factor as a cause of transformer and arrester failures, and to present a limited discussion of laboratory tests and calculations relating to a proposed method of achieving a high degree of protection for equipment so exposed.

Field Experience

After several years' experience with improved station insulation and modern types of carborundum block arresters,[2] it has become apparent that arrester failures are confined to a few exposed locations. Furthermore, most cases of insulation failure are associated with definite evidence of direct strokes to the line near the station.

In one station, no equipment failures have occurred, but arrester failures average one per year. In another station there have been no arrester failures, but transformer failures average one every two years. In still another case, the arrester suffered no damage but a transformer bushing flashed over. This particular bushing had an impulse strength over twice the arrester impedance voltage at 5,000 amperes on the standard AIEE test wave.

Such instances have emphasized the necessity of providing some sort of back-up device which would come into play under extreme conditions only, yet not affect service under the great number of minor surges.

In one station, six-inch rod gaps were installed in parallel with the arresters two years ago, yet another transformer failure occurred in 1940.

As a result of this experience, it was decided to make a series of tests in the laboratory in order to determine if some method could be found to afford protection under such conditions.

Performance of Arresters

In analyzing the performance of lightning arresters subjected to high rates of current rise, it becomes apparent that the so-called IR voltage depends both on the rate of current rise as well as on the maximum value of the current. It has been found that a fair approximation to the actual characteristic can be obtained by using an equivalent circuit composed of a constant voltage, a constant resistance, and a constant inductance in series.

Such representation is, of course, entirely empirical, and serves merely to permit approximate calculations. The method of determining the constants is shown in figure 1. The value of the arrester voltage drop at the time of crest current is plotted for two well-separated values of crest current, and the line joining these points extrapolated to current zero to determine the value of E_a. The slope of this line determines the value of R_a. The difference between the crest of the arrester voltage and the value at the instant of crest current is a measure of the fictitious inductive drop at this time. These values are not strictly constant, but

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Paper 41-102, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16-20, 1941. Manuscript submitted April 8, 1941; made available for preprinting May 6, 1941.

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The author acknowledges the valuable assistance of C. M. Jackson in making the tests, and of E. L. Jarrett in the preparation of this paper.

1. For all numbered references, see list at end of paper.

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ber of the minor parts of our equipment, we purchase the bulk of our plant from the usual equipment manufacturers. Our new 50-kw stations in Toronto and Montreal are Northern Electric transmitters. Those in Sackville and Watrous are RCA. We propose to co-operate with the Canadian Marconi in the operation of an F.M. transmitter on Mount-Royal, Montreal.

All our construction is designed and supervised by our own staff but actual building is assigned by tender to firms who are invited to bid.

Thus, it is seen that radio broadcasting in Canada is conducted under a dual system of individual privately owned stations and of a public service network operated by the CBC. This particular organization, besides having authority to regulate over program contents generally of private stations also owns and operates a number of its own stations and a network composed of both CBC and privately owned stations. Besides, the CBC acts as an agency in booking network programs on all network stations whether they are its own or privately owned. There is also a provision for the setting up of partial networks to meet special demands from sponsors or to take care of the overflow on the national or regional networks. This system has been in operation for more than five years and has proved to meet with the wishes of the very great majority of Canadians across the Country. The public service angle has proved extremely successful in certain instances of national importance and all indications are to the effect that present conditions will be maintained to the best satisfaction of the sponsors, artists, musicians, and the listening public.

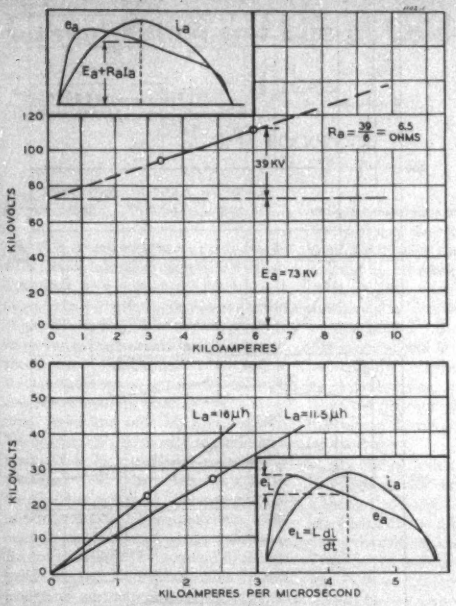

Figure 1. Method of determining constants for equivalent circuit of arrester

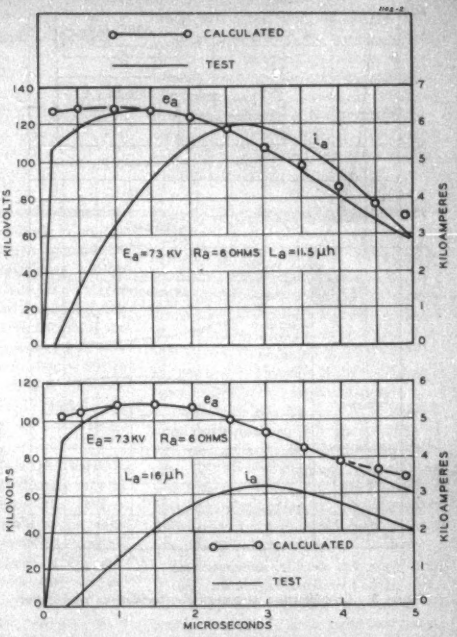

Figure 2. Comparison of test results and calculations from equivalent circuit

decrease with increasing discharge current. Values may be chosen for moderately high current and used with the knowledge that they will be conservative for extreme conditions. Figure 2 shows calculated and measured arrester voltages for the currents and arrester constants shown.

Transformer-Arrester Co-ordination

Because of the relative characteristics of gaps, transformers, and line type arresters, it is not possible to secure complete back-up protection for short times. This situation is illustrated in figure 3 where a modern transformer of the 23-kv class is compared with a modern arrester and a six-inch rod gap.

Gap-Reactor-Arrester Protection

Since the rate of rise characteristic of the arrester is simulated by an inductance, it seemed logical to add an external reactor which would increase the voltage at the gap location for high rates of current rise, and thereby at least partially offset the turn-up in the rod gap characteristic. This scheme is just the reverse of the old arrester-choke coil sequence in that the arrester is transformer-mounted and so limits the voltage at the vital point in the most effective way possible. In the old scheme, the arrester voltages for high rates of current rise were further aggravated by oscillations between arrester and transformer at the natural period of the choke inductance and effective transformer capacitance. In the new scheme, the basic protection is located at the transformer. The inductance and capacitance slope the wave front and lower the arrester breakdown, while the back-up gap is brought into action only when required to keep the arrester impedance voltage at a safe level.

Calculations for Theoretical Scheme

Figure 4 shows such a protection system. Through the substitution of the constant circuit elements to represent the arrester, it is possible to estimate the effect of any assumed terminal current. Although no "turn-up" is shown for the transformer strength, such an increase does exist and would actually provide a greater margin of safety than that indicated. The effect of this protection system at short times is roughly equivalent to the back-up protection of a 3.5-inch gap without the reactor.

Laboratory Tests

Impulse tests were made on the combination protective scheme in order to check the theory within the limitations of the laboratory equipment. Figure 5*a* shows the oscillogram of the voltage across the six-inch gap, while figure 5*b* shows the voltage across the arrester under the same conditions. Figure 5*c* shows the voltage across the arrester for a higher rate of rise of current, and without the reactor.

As a final test of the protection system, it was decided to make a complete set-up including a 100-kva, 3-phase, 22,000/460/230-volt transformer. The particular transformer chosen was an exact duplicate of those mentioned earlier as having flashed over or failed internally three times in six years. The surge generator was adjusted for maximum voltage and all series resistance was short-circuited. Under such conditions, the voltage, if unlimited by gap breakdown, would reach about 650 kv in something less than one-

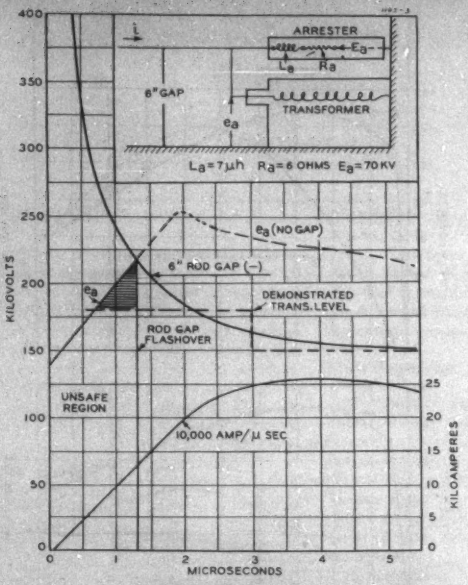

Figure 3. Co-ordination of gap-arrester-transformer combination

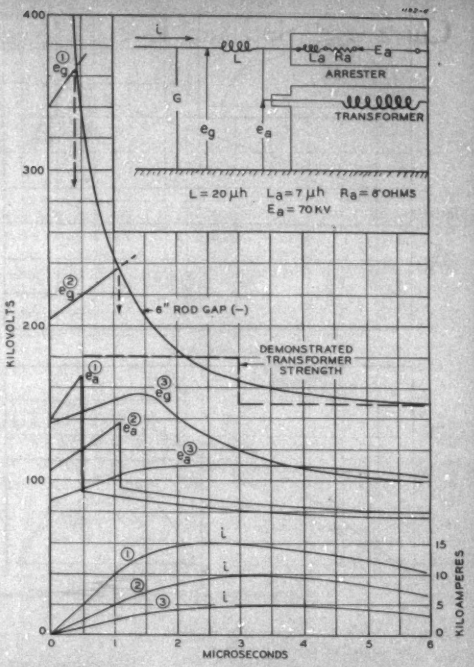

Figure 4. Calculated performance of gap-reactor-arrester protection scheme

half microsecond. Under these conditions, the generator was discharged into the system several times without damage to the transformer. A maximum voltage of 121 kv was recorded at the transformer bushing. Current measurements under such conditions were impossible, but it is estimated that the rate of current rise approximated 20 ka per microsecond.

Following this test, the transformer was subjected to both full wave and chopped wave tests slightly under the present AIEE standard values, and no evidence of insulation failure was detected.

Conclusion

It appears possible to employ a reactor or "choke coil" to compensate for the steep turn-up of rod gaps when the latter are used as back-up voltage limiting devices in conjunction with transformer-mounted lightning arresters. Moreover, such a combination gives promise of providing a high degree of protection to stations fed at subtransmission voltages over wood pole lines without overhead ground wires.

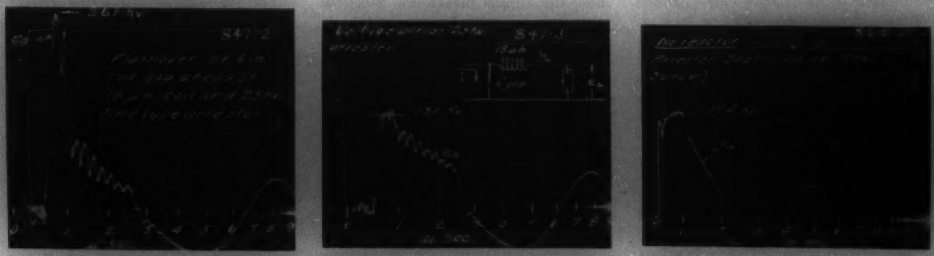

Figure 5. Laboratory tests on gap-reactor-arrester system

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Current Rating and Life of Cold-Cathode Tubes

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Introduction

A COLD cathode tube is a gas discharge device capable of serving as a relay, a rectifier, or a voltage regulator.[1,2] It depends for its action upon the properties of gas discharges. The salient property employed is the fact that there is a difference between the breakdown voltage, or voltage necessary to initiate a discharge, and the sustaining voltage, or voltage drop across the tube when conducting. The principles involved are not new but a practical device capable of operating on voltages of 150 volts or less has awaited the relatively recent development of suitable cathode coating materials. The cathode surface employed at present consists of a coating of barium and strontium oxides applied to a nickel base. These oxides are partially broken down to barium and strontium metal during exhaust. During the operation of the tube the barium is continually removed from the cathode by sputtering and is replaced by further reduction of the oxide reservoir. The life of the tube is limited, therefore, by the amount of material present and by the rate of sputtering.

Because the cold cathode tube requires no cathode heating power it is well adapted to those applications in which the service is intermittent. The absence of a hot cathode implies no deterioration during idle periods and the ability of the tube to start instantly upon the application of an input signal. These properties have opened a wide field of use to the cold cathode tube and it is felt that this field may be widened if the tubes are so rated as to take cognizance of the fact that their life is determined by sputtering and the consequent exhaustion of the reservoir of cathode material. Other gas tubes, such as vapor rectifiers and thyratons, have been rated in terms of peak and average current. These ratings have been based on anode power dissipation and electron emission capability of the cathode surface. In the case of the cold cathode tubes it is desirable to have the rating bear a relationship to the rate of sputtering. For a tube of given manufacture, the rate of sputtering is determined solely by the current drawn. The general form of the life rating should be, therefore, a tabular relationship between the average life to be expected and the current. Several values of current and life are needed since the rate of sputtering is not proportional to the current.

If a cold cathode tube is operated until it fails in service certain changes may be observed visually. These are: first, a dark band on the tube walls in the vicinity of the cathode and, second, a change in color and surface appearance of the cathode. These observations may be accounted for by assuming that the cathode material is lost by either evaporation or sputtering. To test the idea of loss of material due to evaporation thermocouple measurements of the cathode were made. These measurements indicate that, in general, the cathode temperature is less than 250 C and invariably less than 375 C. These temperatures are so low as to make the theory of loss of material by evaporation untenable. For example, the cathode temperature at a current of 35 milliamperes was found to be 210 C and the average life 100 hours. Rudberg and Lumpert[3] have measured the vapor pressure of barium at low temperatures and give a formula by means of which their data may be extrapolated. From this knowledge of the vapor pressure of barium at 210 C and the total amount of barium present on the cathode the life may be calculated and it is found to be 45,000 hours compared to the 100 hours actually observed.

Microchemical examination of the tubes indicates that new tubes have considerable metallic barium on the surface of the cathode together with a much larger amount of barium in combination. Similar tests on tubes which have reached the end of their life indicate less metallic barium on the cathode and almost no barium in combination on the electrodes but the total barium which was present when the tube was made is to be found on other parts of the tube, notably the walls.

These facts lead to the conclusion that as the tube is operated barium is continually lost from the cathode surface by sputtering and is continually replaced from the reservoir of barium oxide provided in the cathode coating. When this reservoir is exhausted the tube reaches the end of its life.

Theory of Cathode Sputtering

Most of the literature on cathode sputtering relates to a discharge at relatively low pressures and with high voltage drops across the tube. The only comprehensive survey of sputtering in low voltage tubes is to be found in a paper by C. H. Townes.[4] A review of the conclusions reached by Townes is given below.

Townes divides the rate of sputtering into three factors: (1) the number of ions of a given energy striking the cathode, (2) the amount of material released by each ion, and (3) the fraction of material released from the cathode which diffuses away and ultimately reaches other surfaces in the tube.

There is good evidence that sputtering is due to ionic bombardment of the cathode and that the material sputtered leaves the cathode in all directions and in an uncharged atomic stage. In the low voltage cold cathode tube the cathode dark space, across which appears the cathode fall of potential has a thickness of several electron mean free paths. The mean free path for a positive ion being smaller than that for an electron, it is evident that very few, if any, positive ions reach the cathode with an energy corresponding to that of the cathode fall. The average energy of positive ions impinging on the cathode is found to be a little less than one electron volt. Not only the average energy is necessary but also the probability that an ion has any of the various possible energies. Appreciable variations in the total energy come principally from the variation in the energy acquired at the last free path of the ion. This follows from the fact that collisions between ions and gas atoms are collisions between particles of substantially equal mass so that on the average, an ion will lose half of its energy at each collision. On the average, therefore, the energy acquired by an ion in its last free path is double that which it had at the beginning of this last free path. The final expression for the distribution in energy of the positive ions striking the cathode is an exponential expression of the same form as that describing the distribution of molecular free paths in a gas. This is to

Paper 41-117, recommended by the AIEE joint subcommittee on electronics, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16-20, 1941. Manuscript submitted April 16, 1941; made available for preprinting May 12, 1941.

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1. For all numbered references, see list at end of paper.

be expected since, as pointed out above, the principal variation in the energy comes from that acquired in the last free path, or in other words depends upon the length of the last free path.

Of the mechanisms suggested for the release of material from the cathode under positive ion bombardment the one most successful in explaining the experimental results is the theory of local heating and resultant evaporation of von Hippel.[4] According to this theory the positive ion delivers its kinetic energy to a small number of atoms on the surface which are temporarily given large random velocities and evaporate from the surface just as they would evaporate if the entire cathode were heated so that they had the same thermal energy. The local hot spot of course, cools very rapidly by sharing its energy with the surrounding atoms. Townes has developed an expression for the number of atoms removed from the cathode by each ion impinging with a given energy. For a cathode material such that an atom must have an energy of four electron volts to escape from the surface his expression leads to the following:

Atoms Removed Per Ion Striking Cathode	Energy of Impinging Ions
2×10^{-8}	4 e.v.
0.2	6 e.v.
3	8 e.v.

This demonstrates the rapid variation in the number of atoms removed per impinging ion as the energy of the impinging ions is increased. The expression for the total number of atoms released from the cathode considering the distribution in energy of the positive ions reaching it is complicated and will not be given here.

Since the mean free path of the sputtered particles is much smaller than the distance between the cathode and surrounding surfaces a large fraction of the atoms which leave the cathode will diffuse back to the cathode surface so that they do not represent a net loss of cathode material. Townes shows that for a fixed rate of evaporation of atoms at the cathode the actual rate of loss of material from the cathode is inversely proportional to the gas pressure and depends as well on the distance to the nearest surfaces where deposition may take place. A large number of the evaporated atoms return to the cathode surface. The exact number lost will, of course, depend upon the tube geometry.

The complete expression for the sputtering rate is given by Townes as:

$$I = AF\frac{J}{p}e^{-\left[\frac{V_0}{c}\left(\frac{p^2}{V_i}\right)^{1/3}\right]} \qquad (1)$$

where

I is equal to the mass per second of sputtered material
p is the gas pressure in millimeters of mercury
V is the cathode fall in volts
i is the current density in amperes per square centimeter
V_0 is the energy in electron volts required to remove one atom from the cathode surface
c is a constant characteristic of the gas. For argon $c=20$, for neon $c=33$
J is equal to the total current
F is a function determined by the geometry of cathode and collecting surface. For plain parallel surfaces $F=1/d$ where d is the distance between the surfaces
A is another constant evaluated in terms of the properties of the cathode material in the gas

The constants in this equation may be approximately evaluated on theoretical grounds or they may be determined by experiment.

Experimental Results

A series of tubes have been operated at various currents to determine experimentally the relationship between current drawn and life. The cathodes of these tubes are coated to a nominal thickness of one-half milligram per square centimeter. This is an extremely thin coating and it is difficult to reproduce such coatings exactly from tube to tube. Considerable scattering in the test results must be expected therefore. The points on the curve of figure 1 each represent the average life of three tubes operated under the current conditions noted. The curve represents equation 1 with the constants so selected that it represents the best fit for the data. The agreement between the curve and the experimental data is seen to be quite satisfactory considering the scattering that must be expected in experiments of this type and suggests that the assumption at the outset that the life of the tubes was determined by the loss of cathode material due to sputtering is correct. This being so it seems reasonable to rate the tubes in such a manner as to reflect this fact.

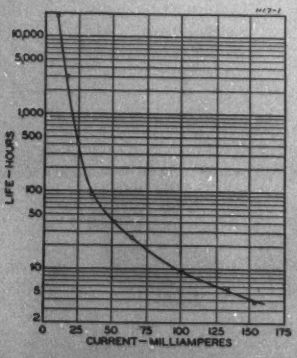

Figure 1. Life of the Western Electric 313C cold-cathode tube as a function of current

The data presented in figure 1 relate to a Western Electric 313C vacuum tube and form the basis for the current ratings for this tube. The ratings employed are those currents which will give a life of 100, 1,000, and 10,000 hours. Because of the large scattering due to variations in coating thickness and gas pressure in individual tubes it is not expected that the life of a single tube can be predicted with an accuracy better than ±50%. In dealing with large numbers of tubes, however, the average life is predicted with a considerably better accuracy. It is practical, for instance, to use this curve in calculating the number of tube replacements required for a circuit which operates under given conditions.

Application of Current Ratings

Since the life of a cold cathode tube of given manufacture depends solely upon the current drawn a knowledge of the relationship between life and current drain is of vital importance to the circuit designer. In the use of cold cathode tubes it often happens that the duty cycle is so light that the life of the tube may be many times the life of the equipment in which it is used even though the tube, if operated continuously, might last but a few hours. If the circuit designer is furnished with the relationship between life and current drain and knows the duty cycle imposed on the tube he is in a position to determine the average life he may expect from the tube. With this knowledge it is often possible to apply small, inexpensive cold cathode tubes to circuits requiring considerable amounts of current for brief and infrequent intervals rather than to resort to larger tubes requiring hot cathodes and capable of supplying the current continuously. Likewise, it makes it possible for the designer to reach a reasonable compromise in decreasing the cost of associated equipment at the expense of increasing the current drain through the tube and therefore shortening the tube life.

If the current wave form through the tube is irregular the life may still be pre-

Dielectric Strength of Oil for High-Voltage Testing of Oil Circuit Breakers

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THE purpose of this paper is to report on work undertaken in response to a request, made to the Institute, to determine the minimum dielectric strength of oil for high potential testing of oil circuit breakers.

Many tests were made with 60-cycle and impulse voltages. The tests were made with a rod to plane gap, cone to disc gap, and on oil circuit breakers of commercial types and sizes. The results of these tests have been collected, analyzed, and are included in tabular form in the paper.

The impulse strength of oil circuit breakers was found to be practically unaffected by the 60-cycle breakdown strength of the oil within the range of 16 to 30 kv, as measured in a standard test cup.

The 60-cycle dielectric strength of oil circuit breakers is shown not to be changed in direct proportion to the differences in the dielectric strength of oil as measured in a test cup with 60-cycle voltage.

The effect of low dielectric strength oil on voltage breakdown is discussed and conclusions are drawn which show that it is desirable to test all oil circuit breakers with oil having dielectric strength of 22 kv or higher.

Paper 41-134, recommended by the AIEE committee on protective devices, and presented at the AIEE summer convention, Toronto, Ontario, Can., June 16–20, 1941. Manuscript submitted April 15, 1941; made available for preprinting May 14, 1941.

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The authors of this paper are the members of a working group of the circuit breaker switch and fuse subcommittee of the AIEE protective devices committee, who were appointed to investigate and recommend the proper dielectric strength of oil for high-potential testing of circuit breakers.

1. For all numbered references, see list at end of paper.

General

The general picture of oil breakdown for some years has involved the lining up of impurities over a period of time ranging from a small fraction of a second to several minutes, with breakdown taking place over the path so formed. From this standpoint it is to be anticipated that long gaps will be relatively less affected by the impurities in the oil than short gaps, and that breakdowns under impulse conditions, where time is not available for lining up of impurities would be less affected by impurities than breakdowns under a one minute test at operating frequency. This is supported by the fact that the impulse ratio of oil, as obtained by comparing Sorensen's[1] data on impulse tests with Miner's[2] data at 60 cycles is considerably greater than the impulse ratio for breakdowns over an air path. Hence, it would be expected that any equipment which will flash over in an air path in preference to an oil path at 60 cycles will have a good margin of safety for the oil under impulse conditions, and it is also to be expected that the dielectric strength of a completed assembly such as an oil circuit breaker would be much less affected by the presence of impurities, in the oil, particularly under impulse conditions, than would be

Table I. Rod-to-Plane Gap Impulse Tests

(See Figure 1)

Gap Spacing (Inches)	Oil	Highest Voltage Held Without Breakdown (Kv)	Lowest Voltage at Which Breakdown Occurred (Kv)
1	New	176	168
1	Old	165	166
2	New	200	186
2	Old	208	190

The tests were made with a 1½-40 m.s. positive wave.

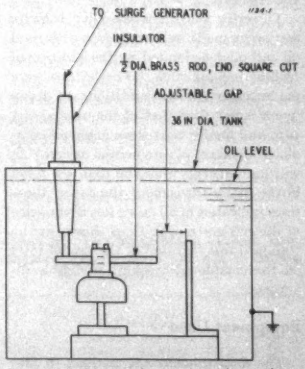

Figure 1. Rod-to-plane gap used in making tests shown in table I

dicted by dividing the current wave into elements small enough so that the current in each element may be considered constant. Each of these currents may then be considered as lasting for a certain fraction of the cycle. For each of the current values obtained there is a life in hours which may be determined from figure 1. One then has a series of currents $i_1, i_2, \ldots i_n$ each lasting for a fraction $t_1, t_2, \ldots t_n$ of the entire cycle and a tube life corresponding to these currents of $l_1, l_2, \ldots l_n$. The fraction of life used up at each current per hour is, then t/l. The total fraction of life used up per hour is

$$\frac{t_1}{l_1}+\frac{t_2}{l_2}+\ldots\frac{t_n}{l_n}$$

and the socket life of the tube is

$$\text{socket life}=\frac{1}{\frac{t_1}{l_1}+\frac{t_2}{l_2}+\ldots\frac{t_n}{l_n}}$$

Conclusions

For tubes manufactured in any given manner the life will be determined solely by the current drawn. In view of the fact that the tubes do not deteriorate when they are not passing current it seems reasonable to operate them at very large currents if the duty cycle is sufficiently light. It is suggested, therefore, that the most useful type of rating for cold cathode tubes would be to state the current which will give a life of 100, 1,000, and 10,000 hours.

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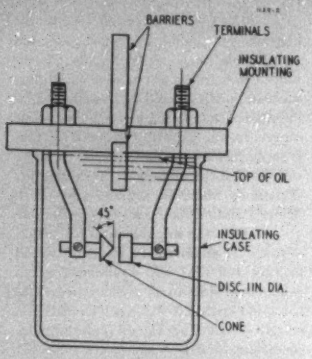


Figure 2. Cone-disc gap used in making tests shown in table II

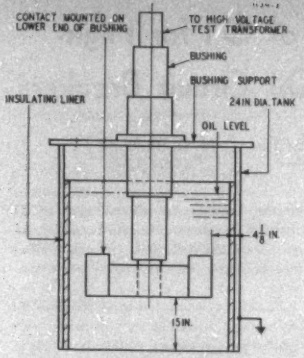


Figure 3. Large gap construction used in making tests in table III

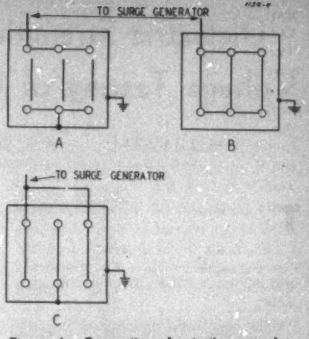


Figure 4. Connections for testing complete circuit breakers 1–10 inclusive, table IV

A. Test on oil across open breaker and to tank
B. Test on all bushings to ground
C. Test phase to phase and to ground

expected from values on oil dielectric strength obtained at 60 cycles in a standard test cup.

To verify this line of reasoning, impulse tests were made on sample gaps with good oil and oil deteriorated by the addition of carbon and moisture, 60-cycle tests were made under similar conditions on a gap much larger than that of the normal test cup, and finally tests were made on completed breakers of commercial design. As will be observed from the data set forth in the tables throughout the paper, these tests indicated in all cases less divergence of dielectric strength than shown in the standard test cup, and in the case of tests on the completed breakers negligible divergence.

Equipment Used

The data used by the authors in preparing this paper were obtained from tests made in the high voltage test laboratories of Westinghouse E.&M. Co. at East Pittsburgh, Pa., and General Electric Company at Schenectady, N. Y., and Philadelphia, Pa.

The oil circuit breakers on which the tests were made were complete commercial designs, sizes, and ratings.

The rod to plane gap was a special gap made by the laboratory and is shown in figure 1. When used for testing, the gap was immersed in a tank of oil.

The cone to disc gap on which tests were made is shown in figure 2.

The wet oil used in making the tests with the cone to disc gap was obtained by forming a saturated solution of water and oil at 80°C. and mixing in measured proportions with oil dried by bubbling dry air through it. The maximum water content was about 250 parts per million.

The used or carbonized oil was obtained from the dirty oil tanks in the laboratory and had previously been used for making oil circuit breaker tests until its dielectric strength had fallen to the point where it was considered necessary to recondition it before further use. In some cases the oil, having been taken from near the bottom of the tank, contained more than the usual amount of foreign material. When let stand without agitation for a short time, these materials tended to settle at the bottom of the tank. This accounts for the fact that in some cases the test value of the oil measured in a standard test cup with 60-cycle voltage varied from 4 to approximately 15 kv.

For the purpose of obtaining data on the dielectric strength of large gaps, using deteriorated oil, a 24-inch circuit breaker tank was filled with oil and a crosshead of corresponding size was supported in the tank in a position corresponding with that which it takes when the breaker is closed. An electrical connection was made to this crosshead through a high voltage bushing, and the tank itself was used as a ground terminal. See figure 3.

Impulse Tests on Rod-to-Plane Gap

Impulse tests were made on a rod to plane gap shown on figure 1. Tests were first made with new oil and then repeated with used oil. The new oil tested about 30 kv in a standard oil test cup. The

Table II. Cone-to-Disk Gap Impulse Tests (See Figure 2)

Ratio of Dielectric Strength Values

	60 Cycles		0.5 M.s.		1.5 M.s.		3 M.s.	
	Std. Gap	Cone Disk Gap	Cone Pos.	Cone Neg.	Cone Pos.	Cone Neg.	Cone Pos.	Cone Neg.
Good oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Carbonized oil	0.43	0.43	0.83	0.89	0.72	0.76	0.60	0.62
Wet oil	0.26	0.40	0.89	0.78	0.89	0.80	0.86	0.70

Table III. Low-Frequency Tests on Large Gaps (See Figure 3)

	Oil Dielectric Standard Test Cup Strength		60-Cycle Test With a Large Gap			
	Kv	Ratio	Voltage Held Quietly (Kv)	Noisy (Kv)	Breakdown Voltage (Kv)	Ratio* Max. Quiet
Good oil	30		130	135	150	
Carbonized oil	9	0.30	115	**	118	0.89
Wet oil	14	0.47	112	115	146	0.86

*The values in this column are the ratios of the maximum voltage held quietly by the deteriorated oil, to the maximum voltage held quietly in good oil.

**No noisy region found between voltage held quietly and breakdown.

used oil was taken from a breaker which had undergone severe interrupting duty. The breakdown of the used oil was erratic, varying from 5 to 15 kv.

In these tests, the gap was immersed in the tank filled first with new oil and then with used oil. The tests indicated that the impulse breakdown of the low test oil was as high as that of the new oil. Tests were made with the gap set at one inch and at two inches with results as given in table I.

The small difference in test voltage shown for the two gaps is possibly due to corona forming on the gap electrode at the higher voltage and reducing the voltage required to break down the longer gap.

Impulse Tests Made With a Cone-to-Disk Gap

The tests were made with a 45° cone disc gap, figure 2, with a spacing of 0.025" using:

(*a*). Good oil
(*b*). Carbonized oil
(*c*). Wet oil

The tests were made with the time to crest at 0.5 m.s. and 8 m.s.

From these values a figure for 1.5 m.s. has been interpolated for use in connection with the standard impulse wave. Table II shows the ratio of dielectric strength values between the good oil taken as 1.00 and the carbonized and wet oils respectively. Each of the impulse values in table II was determined by making approximately 100 tests.

It will be observed that the presence of carbon or water in the oil does not affect the ratio under impulse conditions to the same extent as under steady state voltage conditions.

Tests Made With 60-Cycle Voltage on Large Spacings

Tests were made to determine how the variation in the dielectric strength of oil as measured by the standard gap is reflected in the dielectric strength of a larger assembly such as an oil circuit breaker; the equipment used in making these tests was described previously, and is shown in figure 3. High potential tests were made to determine what 60-cycle voltage could be held for one minute without breakdown or audible internal disturbance. Results are given in table III.

It will be observed that there is a much lower spread in the dielectric strength of oil in a large gap than might be anticipated from the spread in dielectric strength values with the standard gap.

Impulse Tests on Complete Oil Circuit Breakers With New and Old Oil

Impulse tests were made with a $1^1/_2$–40 m.s. positive wave on 12 complete oil circuit breakers to determine if the impulse strength of breakers would be appreciably lowered by carbon or water or both in the oil. The breakers were tested with new oil and then retested with old oil.

The new oil used to test breakers 1–10 inclusive was taken from standard package containers and tested 30 kv in a standard test cup.[3] The used oil with which these breakers were tested was taken from the dirty oil tanks in the high power laboratory and tested from 4 to 16 kv.

Breakers 1–10 inclusive were small three pole breakers with all three poles in a common tank. The results of the tests on these breakers are given in table IV which follows immediately.

Tests on Complete Circuit Breaker 11

Breaker 11 was a single pole of a three pole breaker with each pole in a separate tank. The bushings in this breaker had a higher than usual flashover strength in relation to the breakdown strength of the oil between the contacts and the tank. This condition made it possible to obtain breakdowns through the oil in the tank. The tests were made with the breaker closed and both bushings connected to the surge generator. The results of the tests with oils of different dielectric strength are contained in table V. All tests were made with a $1^1/_2$–40 m.s. positive wave.

Test on Complete Circuit Breaker 12

The tests on breaker 12 were made on poles 1 and 2 of a three pole high voltage frame mounted breaker with each pole in a separate tank. Pole 1 was filled with good oil testing between 26 and 27 kv. Pole 2 was filled with oil taken from breakers in service on the shop lines. This oil tested slightly under 19 kv. For convenience in table VI these oils are considered to have test values of 26 kv and 19 kv respectively. The tests made on breaker 12 and shown in table VI show the 26-kv oil to have a slightly higher impulse breakdown value than the

Table IV. Tests on Complete Common Tank Breakers

Tests on Completed Circuit Breakers 1 to 10 Inclusive

Breakers Tested	Lowest Flashover (Kv)		Highest Full Wave Withstood (Kv)	
	New Oil Testing 30 Kv	Old Oil Testing 4–16 Kv	New Oil Testing 30 Kv	Old Oil Testing 4–16 Kv
Breaker 1	44	44	46	44.5
" 2	40.5	42.5	41.5	40.5
" 3	51.5	51.5	52.1	52.7
" 4	49	52.1	53.5	54
" 5	63.4	65.5	76	78
" 6	80	83.5	81	84
" 7 Closed	97	97	106	108.5
" 7 Open	102	90	104	97.2
" 8 Closed	122	121	133	122
" 8 Open	115	120	116	127
" 9 Closed	119	118	130	121
" 9 Open	96	97	103	101
" 10	127	127	148	148

All flashovers were outside of breaker.

Each of the above values is the lowest flashover or highest full wave of 15 tests.

Table V. Tests on Complete Separate Tank Breaker With Oversize Bushings to Secure Breakdown in Oil

	Oil at 30 Kv	Oil 34.5 Kv at Top and 16 Kv at Bottom	Oil at 23 Kv	Oil at 15–17 Kv
Breaker 11	250 kv *B*.	226 kv .	217 kv .	294
	249 *B*.	223	2-220	292
	246 *B*.	229	223	297
	238 *B*.	240 *B*.	227	294
	237 *B*.	240	228 *B*.	302 *B*
	230 *B*.	242	2-233	304 *B*
	235 *B*.	245	228	2-293 *B*
	232 *B*.	248	229	284
	223 *B*	2-256	231	278
	226 *B*.	267	2-235	281
	2-226	272 *B*.	244 *B*.	287
	222	2-272	237	294
	224	278 *B*.	2-236	295
	227	2-278	238	308
	226 *B*.		239	2-297
	2-223 *B*.		240	2-296 *F*
	225 *B*.		242	294 *F*
	223		247 *B*.	2-289
	226	2-246		294
	214 *B*.		244	301
	212 *B*.	2-250		303
	221 *B*.		253 *B*.	309 *F*
	227	2-260		
	228	2-265		
	226 *B*.	265 *B*		
Average.	228+	254−	241−	295+

B = Broke down through oil to tank.

F = Flashover bushing outside of breaker.

The numeral 2 appearing at the left of a test indicates that two tests were made.

Table VI. Tests on Complete Separate Tank Breaker With Various Striking Distances in Oil

	Full Striking Distance Through Oil		Striking Distance Through Oil Reduced to 35 Per Cent of Full Amount		Striking Distance Through Oil Reduced to 19 Per Cent of Full Amount	
	Oil at 26 Kv	Oil at 19 Kv	Oil at 26 Kv	Oil at 19 Kv	Oil at 26 Kv	Oil at 19 Kv
Breaker 12	3-351	3-351	3-258	3-258	258 *B*	3-192
	3-392	3-392	3-285	3-285	3-192	3-205
	3-432	3-432	3-312	3-312	3-205	3-218
	2-473 *F*	2-473 *F*	3-338	3-338	3-220	3-231 *B*
	5-432	452 *F*	3-372	3-372	345	3-231
	2-439 *F*	452	3-405	2-405	345 *B*	231 *B*
	459 *F*	452 *F*	446	405	345	231
	459	4-432	2-446 *F*	446 *F*	345 *B*	231 *B*
	459 *F*	432 *F*			345	5-344 *B*
	4-540 *F*	432			3-258 *B*	
		3-452			3-258	
		452 *F*			258 *B*	
		462			3-258	
		4-473 *F*			3-258 *B*	
		4-554 *F*			285 *B*	
					385	
					385 *B*	
					285	
					4-298 *B*	
					5-234	
					3-304 *B*	
					364	

The numerals 2, 4, 3, 5, appearing at the left of a number indicate the number of tests made at that particular voltage.

19-kv oil. This is contrary to the results obtained on breakers 1 to 11 inclusive and is probably due to the difference resulting from the two oils being tested in different tanks and on different poles of the breaker. All tests were made with the breaker open, one stud impulsed, frame and all other studs grounded. Approximately 15 seconds elapsed between tests. Both poles were tested and the results given in columns 1 and 2 of table VI. In these tests neither oil could be broken down. All flashovers—marked *F*—occurred in air over the outside end of the bushing. The poles under test were then changed by inserting 2"x1/4" copper bar between the contacts and the tank cover to reduce the breakdown distance through the oil to the tank to 35% of the original distance. The tests in columns 3 and 4 were made and again the flashovers occurred through the air over the outer end of the bushing.

The breakdown distance through the oils was further reduced until it was only 19% of the original distance. Tests shown in columns 5 and 6 of table VI were then made. Breakdowns were obtained on pole 1 in good oil at a minimum of 245 kv. In pole 2 breakdowns were obtained through the 19-kv test oil at a minimum of 231 kv as indicated by the letter—*B*. All tests were made with a 1 1/2–40 m.s. positive wave.

Discussion of Test Results and Conclusions

The test data indicate that the presence in the oil of moisture, carbon, and other materials, normally tending to lower the 60-cycle dielectric strength of oil, appears not to change appreciably the ability of oil circuit breakers to withstand impulse voltages.

Table I shows that the impulse strength of large gaps in oil is practically constant for oils of different dielectric strength, within the range regularly used.

Table II shows that the impulse strength of small gaps in oil varies, but not directly, with the 60-cycle strength of the oil.

Table III shows that the 60-cycle breakdown strength of the breaker is reduced when the dielectric strength of the oil is lowered, but much less than in proportion to the loss of strength in the oils as measured in a standard oil test cup.

Table IV shows that the impulse strength of ten small oil circuit breakers of different types and ratings was not lowered when they were tested with poor oil.

Data in table V, from tests made on a medium size outdoor breaker, show that the impulse strength of an oil circuit breaker might in some cases be better with poor oil than with good oil.

Data in table VI, from tests made on a large outdoor oil circuit breaker, show the impulse strength of large breakers to be practically unaffected by the 60-cycle strength of the oil within the range regularly used.

Oil for circuit breakers and transformers[4] is purchased with a minimum breakdown value of 22,000 volts. Since oil of this or higher strength is most easily obtained, the authors recommend that the oil used for high potential testing of oil circuit breaker, both 60 cycle and impulse, should have a dielectric breakdown strength of 22 kv or higher, the breakdown strength to be determined as prescribed by the American Society for Testing Materials.[3]

It is to be noted that apart from any reduction in dielectric strength resulting directly from the use of deteriorated oil as an insulating medium, there is a tendency for carbon particles to settle out from the oil upon insulating surfaces. This may in time decrease the creepage strength of these surfaces much more than the breakdown strength through the insulating medium is decreased, and constitutes the greatest danger from allowing poor oil to remain in the breaker. Consequently, the test results reported in this paper are not to be interpreted as suggesting any relaxation of maintenance activities in this respect.

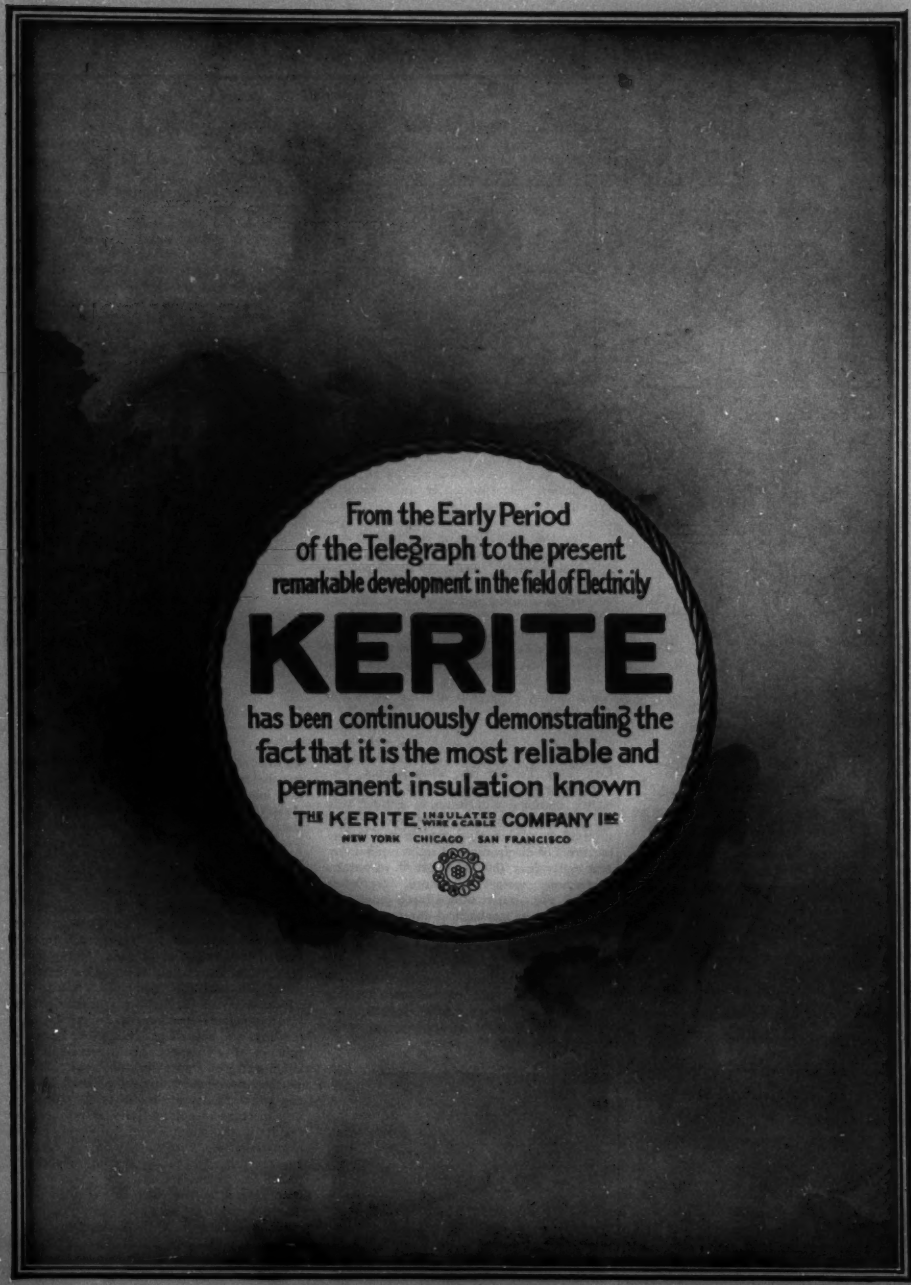
References

1. Surge-Voltage Breakdown Characteristics for Electrical Gaps in Oil, Royal W. Sorensen. AIEE Transactions, volume 59, 1940 (February section), pages 78–81.

2. Oil Breakdown at Large Spacings, Douglas F. Miner. AIEE Transactions, volume 46, 1927, page 248.

3. Standard Methods of Testing Insulating Oils. ASTM *Standards* D117-36.

4. ASA Proposed American Standards for Transformers, Regulators, and Reactors. C57. 1-2.050.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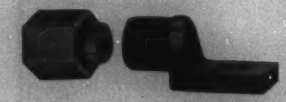

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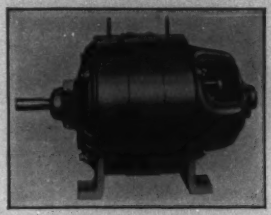

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number of units may be grouped together in parallel to meet the demands for heavy current loads; or the units may be grouped in series for maximum high voltage requirements.

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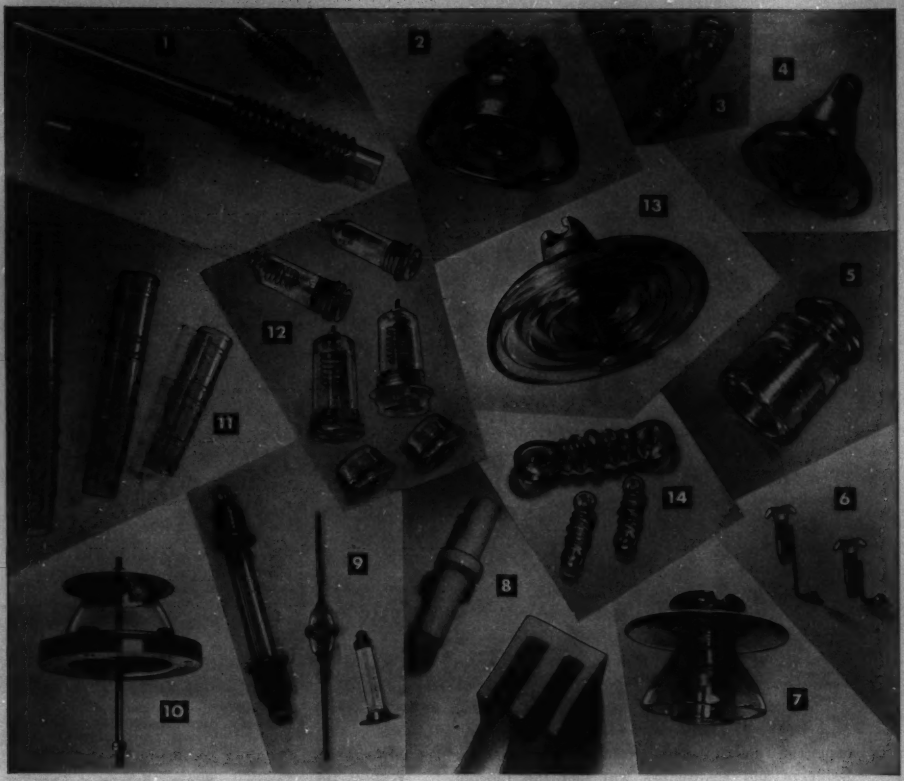

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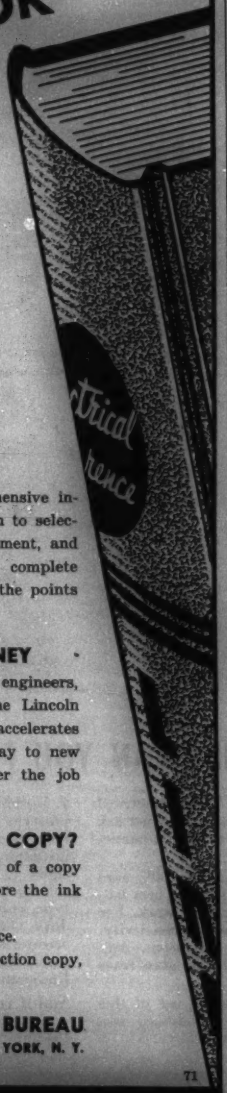

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Capacitors.—Catalog 164, 36 pp. A combined manual of useful engineering data and illustrated catalog of standard capacitor construction. Describes industrial capacitors for motor starting and other a-c applications. Cornell-Dubilier Electric Corp., South Plainfield, N. J.

Power Assembly Tools.—Data Book, 56 pp. Describes portable electric screw drivers, nut runners and tappers. Includes information as to sizes of pilot holes; bolt, nut, cap screw and lag screw sizes; socket wrenches; tap drill sizes, etc. The Black & Decker Mfg. Co., Towson, Md.

Transformers.—Bulletin TU-34, 4 pp. Describes a new type of rural line transformer which has integral protection against both surges and overloads. Wagner Electric Corp., 6400 Plymouth Ave., St. Louis, Mo.

Terminal Blocks.—Bulletin. Describes built-up molded terminal blocks, consisting of molded sectional units, available in any number of terminals up to 50. Curtis Development & Mfg. Co., 3226 N. 33d St., Milwaukee, Wis.

Circuit Breakers.—Bulletin B-6165, 4 pp. Describes small outdoor circuit breakers of the frame mounted type, rated 50,000 kva, 7,500 volts, 400 to 600 amperes, for circuit protection in moderate capacity applications. These quick-clearing (8-cycle) breakers of non-oil-throwing design, manually or electrically operated, are especially suited for automatic reclosing service in outlying districts. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

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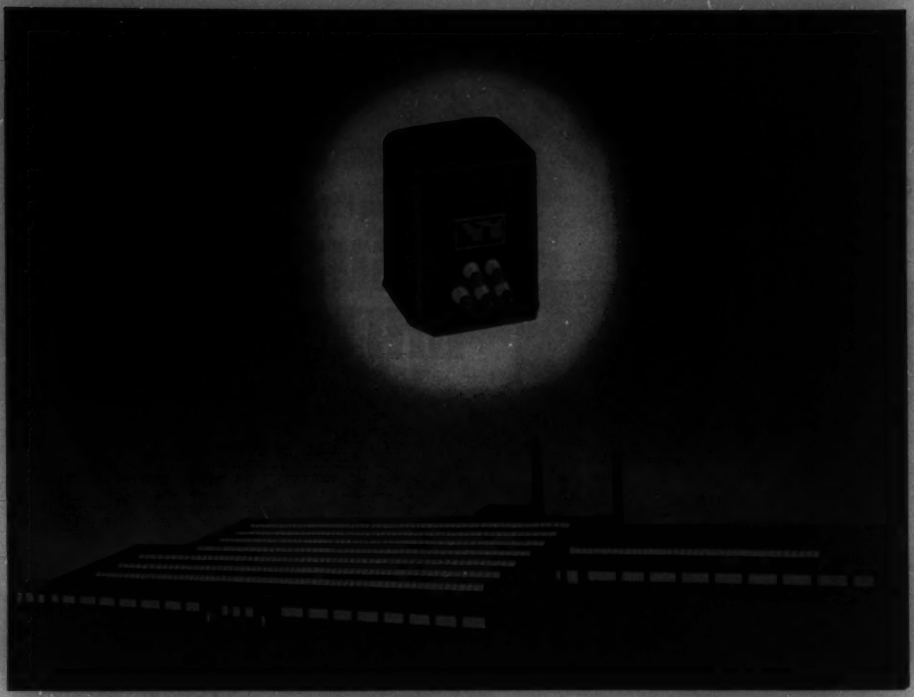

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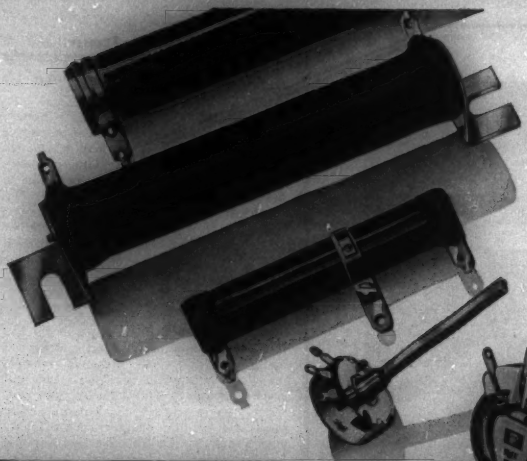

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Lightning Protection.—Catalog 415, 112 pp. Includes much engineering information on lightning protection for distribution systems and equipment, and technical and catalog data on Crystal Valve lightning protective equipment. This comprehensive publication contains chapters such as Lightning Protection for Distribution Systems, Fundamentals of Lightning Protection, Transformer Failures Due to Lightning, Interconnection, Balanced Protection, Protection for Rural Lines, Performance Characteristics of Arresters, and others. Electric Service Supplies Co., Philadelphia, Pa.

Turbine Generators.—Bulletin GEA-3277-1, 78 pp. Describes turbine generators from 500 to 7,500 kilowatts. Contains photos and charts which show the major steps in manufacture. Sectional views of turbines, valve mechanisms, interconnecting mechanisms, generators, exciters and ventilation are given, as well as detailed sketches of various turbine types—straight condensing and noncondensing, condensing single and double extraction, noncondensing single and double extraction and superposed. General Electric Co., Schenectady, N. Y.

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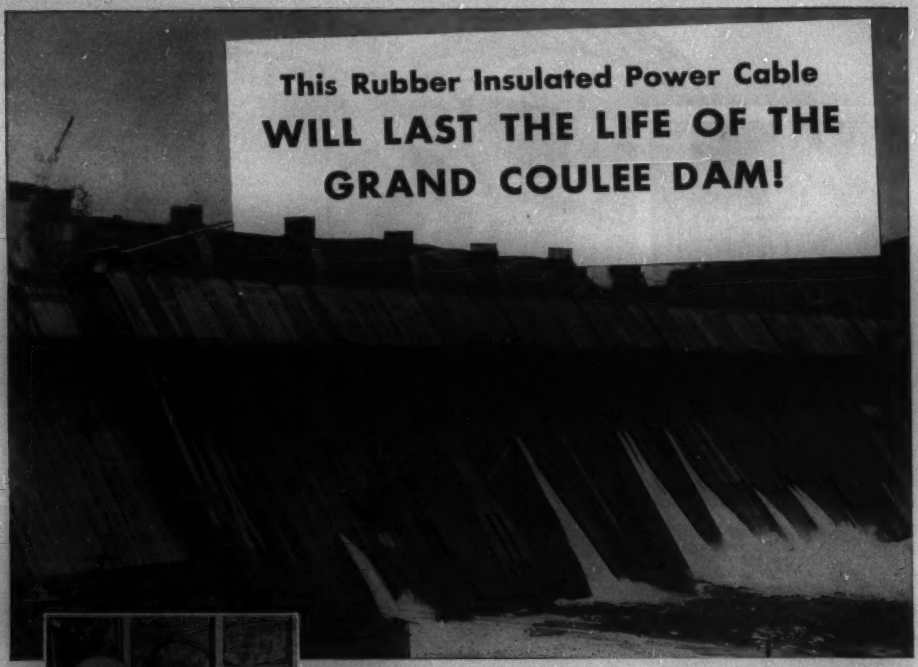

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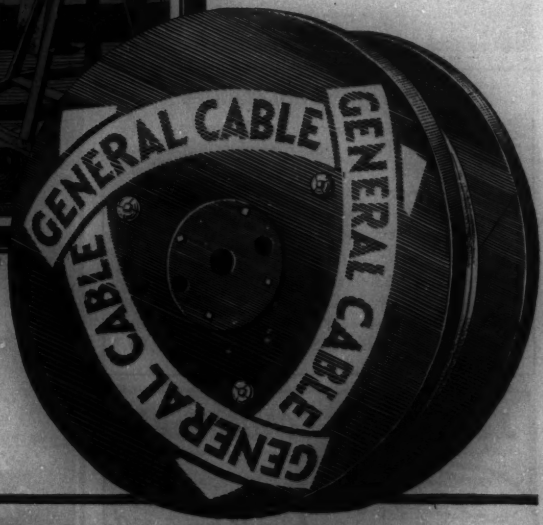

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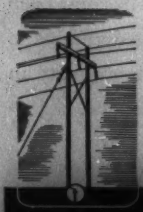

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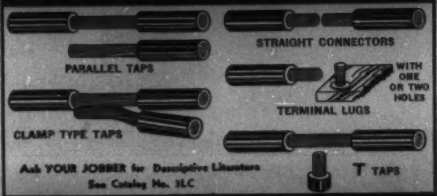

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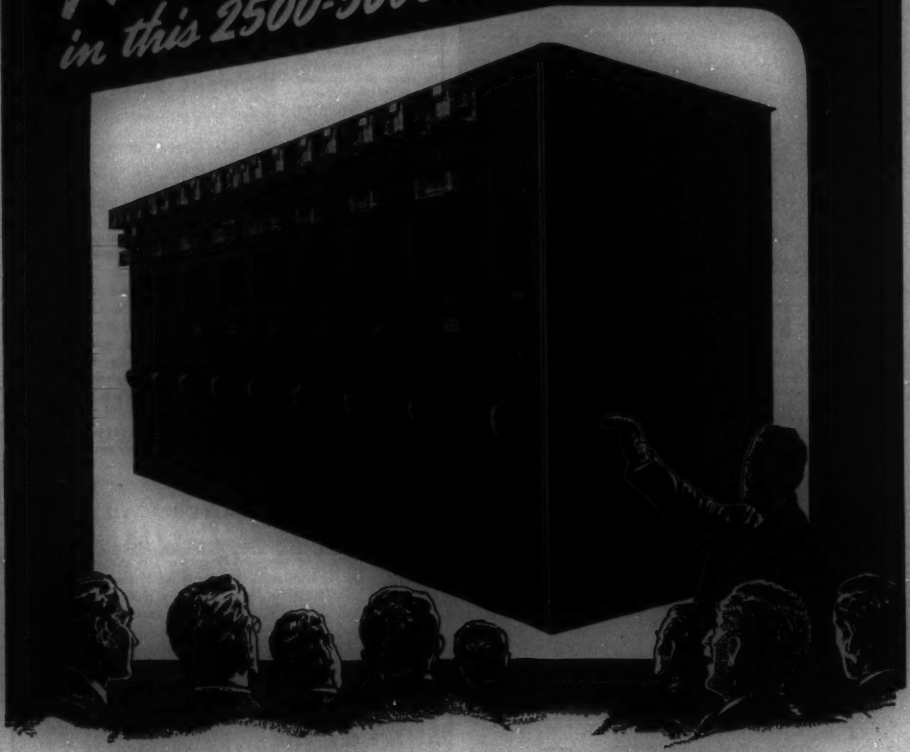

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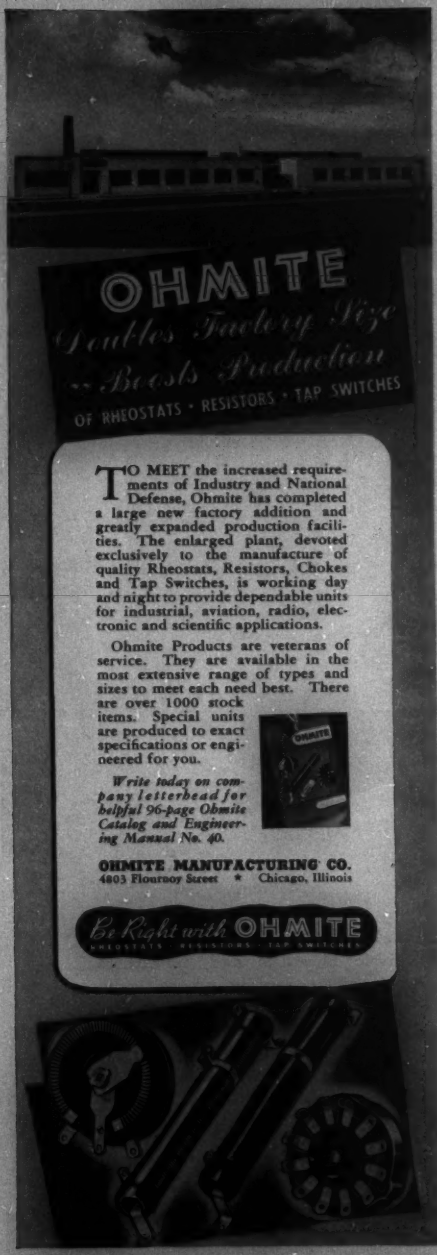

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D-C TEST CODE

The AIEE Test Code for Direct-Current Machines, No. 501, which has been available as a report for several years, has been approved by the Board of Directors as an accepted code under date of May 23, 1941. This code has been prepared under the auspices of the AIEE Committee on Electrical Machinery. The purpose of this code is to define acceptable methods of making tests to determine that the performance and other characteristics of d-c machines comply with those guaranteed.

The following tests applicable to all d-c generators and motors are covered: Insulation resistance, resistance of windings, potential drop and polarity of field coils, brush setting, running light losses, magnetic saturation, core loss, efficiency, telephone interference factor, commutation, voltage regulation, speed regulation, load tests for fractional horsepower motors, temperature tests, shaft currents, dielectric tests, exciter response. Cost, 50 cents per pamphlet, with the usual 50 per cent discount to members on single copies.

FUSES ABOVE 600 VOLTS

A considerably revised edition, prepared by the AIEE Committee on Protective Devices, of Report No. 25, Proposed Standards for Fuses Above 600 Volts, is now available. The new report gives much additional data, particularly on dielectric tests, interrupting tests and time-current tests. Tables of test values are now given applying to both indoor and outdoor type fuses for alternating voltage, one-minute dry tests and for impulse tests. There is no charge for copies of this pamphlet.

SWITCHGEAR ASSEMBLIES

The Committee on Protective Devices of the AIEE has prepared an addenda sticker for insertion in Pamphlet No. 27A, proposed revision of AIEE Standard No. 27, Switchgear Assemblies. The addenda consists of a footnote to Rules 27–250 and 27–252 and reads as follows: "For test purposes a temperature rise of 45 degrees C over the outside ambient will be accepted as meeting the requirements of Rules 27–250 and 27–252." No charge is made for these stickers.

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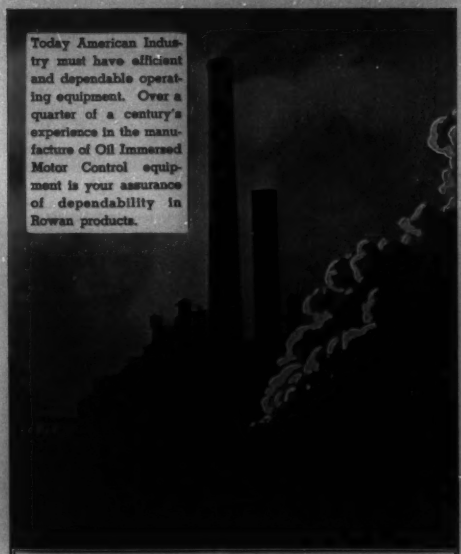

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The report "Telemetering, Supervisory Control, and Associated Circuits," just published, was prepared by joint subcommittee of the AIEE committee on automatic stations and the AIEE committee on instruments and measurements. Corrected to December 1940, this publication summarizes a wealth of information concerning the electric telemetering and supervisory-control systems currently in use or commercially available in the United States, and includes a detailed discussion of the interconnecting circuits suitable for such purposes.

In recognition of the ever-widening field of application for telemetering equipment, the report has been prepared in such form and terminology as to make it readily useful to engineers in any branch of industry likely to be concerned with problems of remote measurement and control. Extensive tabulations giving comparative data are designed to enable a prospective or existing user of telemetering or supervisory control equipment quickly to determine the type of apparatus best suited to his requirements.

All known commercial sources of telemetering and supervisory control apparatus in the United States have been canvassed, and every effort made to present a complete picture of the instruments and systems available for the purpose. The work is based upon a report compiled by an AIEE subcommittee in 1932, although the coverage has been extended and of course the information has been brought fully down to date. Indexed; includes a selected biography on telemetering systems and methods.

"Telemetering, Supervisory Control, and Associated Circuits" . . . Printed pamphlet, 28 pp., 8½ by 11 inches; 40 cents per copy to AIEE members (80 cents to non-members). Discount of 20% on quantities of 10 or more copies mailed to one address at one time. Remittances in New York exchange should accompany orders.

Bibliography of Relay Literature

A "Bibliography of Relay Literature, 1927–1939," published in July, was sponsored by the AIEE committee on protective devices and was prepared by a working group of the relay subcommittee. This subcommittee reviewed available indexes and from these compiled this list of significant articles dealing with protective relaying and also with closely related subjects, including all such material published in AIEE TRANSACTIONS or ELECTRICAL ENGINEERING from January 1927 through December 1939, and most of those in the principal technical publications of the world from January 1932 to December 1939.

The 450-odd annotated reference items are divided into the following subject sections, and in each section entries are consecutively numbered and listed alphabetically by years: Line Protection (Distance, Pilot Wire and Carrier Current, Ground Faults, General), Bus Protection, Apparatus Protection, Distribution and Network Protection, Service Restoration, General and Miscellaneous Relaying, Testing and Analyzing, System Stability, Methods of Calculation, and Instrument Transformers and Other Auxiliary Devices.

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Roller-Smith Co., Bethlehem, Pa.
Weston Elec. Instrument Corp., Newark, N. J.
Westinghouse E. & M. Co., E. Pittsburgh

RESISTORS
General Electric Co., Schenectady, N. Y.
General Radio Co., Cambridge, Mass.
International Resistance Co., Philadelphia
Ohmite Mfg. Co., Chicago
Shallcross Mfg. Co., Collingdale, Pa.
Westinghouse E. & M. Co., E. Pittsburgh

RHEOSTATS, LABORATORY
General Electric Co., Schenectady, N. Y.
General Radio Co., Cambridge, Mass.
International Resistance Co., Philadelphia
Ohmite Mfg. Co., Chicago
Westinghouse E. & M. Co., E. Pittsburgh

STEEL, ELECTRICAL
Carnegie-Illinois Steel Corp., Pittsburgh

SWITCHBOARDS
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
I-T-E Circuit Breaker Co., Philadelphia
Roller-Smith Co., Bethlehem, Pa.
Westinghouse E. & M. Co., E. Pittsburgh

SWITCHES, AUTOMATIC TIME
General Electric Co., Schenectady, N. Y.
Mineralac Electric Co., Chicago

SWITCHES, DISCONNECT
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., Bethlehem, Pa.
Westinghouse E. & M. Co., E. Pittsburgh

SWITCHES, GENERATOR FIELD
I-T-E Circuit Breaker Co., Philadelphia
Roller-Smith Co., Bethlehem, Pa.

TOWERS, TRANSMISSION
American Bridge Co., Pittsburgh

TRANSFORMERS
Acme Elec. & Mfg. Co., Cuba, N. Y.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Chicago Transformer Corp., Chicago, Ill.
Ferranti Electric, Inc., New York
General Electric Co., Schenectady, N. Y.
General Radio Co., Cambridge, Mass.
Kuhlman Electric Co., Bay City, Mich.
Roller-Smith Co., Bethlehem, Pa.
Sola Electric Co., Chicago
United Transformer Corp., New York
Westinghouse E. & M. Co., E. Pittsburgh

TURBINES and TURBINE GENERATORS
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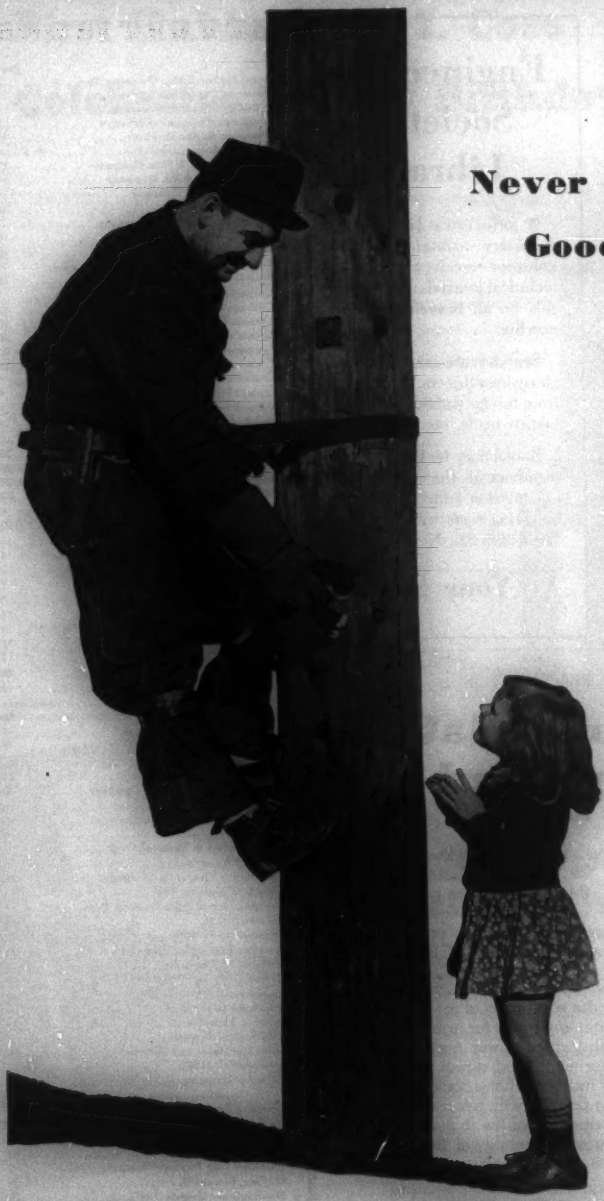
General Electric Co., Schenectady, N. Y.
Westinghouse E. & M. Co., E. Pittsburgh

VARNISHES, INSULATING
General Electric Co., Bridgeport, Conn.
Irvington Varnish & Ins. Co., Irvington, N. J.
Westinghouse E. & M. Co., E. Pittsburgh

WELDERS, ARC
General Electric Co., Schenectady, N. Y.
Westinghouse E. & M. Co., E. Pittsburgh

WELDING WIRE
American Steel & Wire Co., Cleveland, O.
General Electric Co., Schenectady, N. Y.
Roebling's Sons Co., John A., Trenton, N. J.

WIRES AND CABLES
Aluminum Co. of America, Pittsburgh
American Steel & Wire Co., Cleveland, O.
Belden Mfg. Co., Chicago
Copperweld Steel Co., Glassport, Pa.
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
National Elec. Products Corp., Pittsburgh
Okonite Company, The, Passaic, N. J.
Okonite-Callender Cable Co., Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.



Never too busy to be Good Neighbors

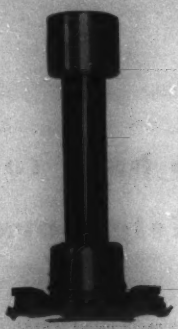
THERE are a lot of workers in the Bell System — about 350,000 of them. That's a big family and it likes to be a friendly kind of family.

Whether it be the installer in the house, the people in our offices, the operators or the lineman on the roadside helping to rescue a stray kitten for a worried youngster, telephone workers are close to the public and the tradition of the job is helpfulness.

Even in these days when the needs of defense place sudden and increasing demands on telephone workers, they are never too busy to be good neighbors.

Bell Telephone System

"The Telephone Hour" is broadcast every Monday. (N.B.C. Red Network, 8 P.M., Eastern Daylight Saving Time.)



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Carefully shielded, primary standard of zero power factor, compressed-gas dielectric, for use at high voltage and power frequencies.

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Engineering Societies Library

A reference library for engineers—contains 150,000 volumes—receives over 1,300 technical journals and periodicals on all branches of engineering.

Searches are made upon engineering subjects, translations from foreign publications, photostats made, etc.

Books may be borrowed by members of the AIEE. For information address, The Engineering Societies Library, 33 West 39th St., New York.

At Your Service

RECOMMENDED PRACTISE FOR

Electrical Installations on Shipboard

(MARINE RULES)

Sec. No. 45 AIEE Standards With Addenda as of March 1941

THE latest edition of "Recommended Practise for Electrical Installations on Shipboard" (Marine Rules) is published as Section 45 of the AIEE Standards. The pamphlet contains 100 pages; price is $1.50 (50% discount to members of the AIEE).

These rules have been drawn up to serve as a guide for the equipment of merchant ships with electrical apparatus for lighting, signaling, communication, power and propulsion for both alternating and direct current systems. They indicate what is considered good engineering practise with reference to safety of the personnel and of the ship itself, as well as reliability and durability of the electrical apparatus.

American Institute of Electrical Engineers

33 West Thirty-Ninth Street, New York

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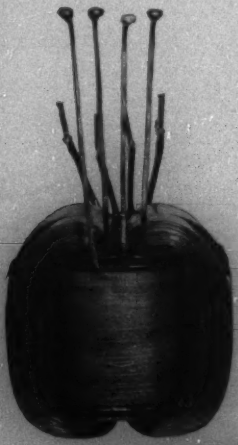
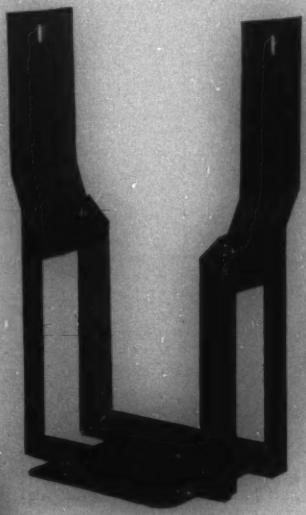
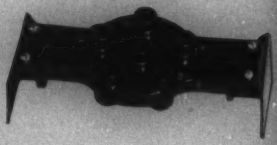
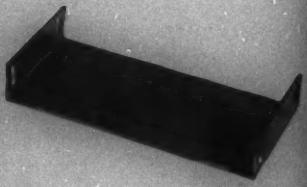
First Kuhlman B. I. Core Celebrates its 12th Birthday









Shown in the colored panel are (1) the Kuhlman Bent Iron Core as it was first built in 1935, (2) the frame for the core, and (3 and 4) the original top plate and porcelain terminal block. Immediately above is shown the Kuhlman B. I. Core as it is built today.

B. I. Core of today incorporates many improvements

It was a mighty important step forward when, in 1929, Kuhlman's chief engineer, W. F. Gakle, developed a one-joint laminated core that could be formed around the coil. In brief, the Kuhlman Electric Co. made transformer history in 1929 by originating the Kuhlman Bent Iron Core.

Laboratory and field tested for six years the Kuhlman B. I. core was put into production in 1935 and since then has turned out to be the greatest improvement in transformer construction in 50 years.

Technically, the big advantage of this core construction is in its (1) direction of magnetization (2) single joint and (3) economical use of material. These factors bring about higher permeability, lower hysteresis, lower exciting currents, lighter construction, lower impedance and better regulation.

Improved and refined many times since its inception, today, the Kuhlman Bent Iron Core utilizes, to the fullest extent, the most desirable characteristics inherent in present day material. For further facts write today for Bulletin 413.

KUHLMAN ☆ ELECTRIC COMPANY

Below is a reproduction of a section of the new Engineering Data and Property Chart, No. 416. A full size chart in colors, complete with graphs showing physical characteristics difficult to express in figures, will be sent free on request. Address: American Lava Corporation, Chattanooga, Tenn.

PROPERTIES OF CERAMIC INSULATING MATERIALS OF THE AMERICAN LAVA CORPORATION

The data below represents average rather than optimum values obtained on standard test pieces. While these data are typical, it is well to remember that they may vary slightly depending upon size, shape, and method of manufacture of the article in question and the uses to which put. Values omitted in the table are of no importance considering the technical use of the material.

ITEM	UNIT	TEST METHOD	ALSiMAG 35	ALSiMAG 196	ALSiMAG 197	ALSiMAG 211	ALSiMAG 72	ALSiMAG 202	ALSiMAG 203	ALSiMAG 222	ALSiMAG 190	ALSiMAG 192	LAVA GRADE "I"	LAVA GRADE "M"	LAVA GRADE
TYPE OF MATERIAL			Dense steatite materials, consisting chiefly of clinoenstatite crystals, ($MgO \cdot SiO_2$)				Magnesium-aluminum-silicates, consisting chiefly of cordierite crystals. ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$)		Aluminum silicate, consisting chiefly of mullite crystals. ($3Al_2O_3 \cdot 2SiO_2$)	Magnesium silicate	Titanium dioxide materials, consisting chiefly of rutile crystals. (TiO_2)		Natural fired stone magnesium silicate.		Natural fired stone aluminum silicate
PREDOMINANT CHARACTERISTICS		A.S.T.M. METHOD NUMBER UNLESS OTHERWISE SPECIFIED	Good electrical characteristics, high mechanical strength, close dimensions.	Low dielectric loss, good electrical characteristics, high mechanical strength.	High dielectric strength, low dielectric loss. High mechanical strength.	Extremely low dielectric loss at temperatures. High mechanical strength.	Low coefficient of thermal expansion. Can be fired and electrical properties. Can only be extruded, not pressed	Low coefficient of thermal expansion. Can be fired and electrical properties. Can be extruded, and machined dry as in compression.	Highly refractory body.	A refractory material which can be used in the fired state.	High dielectric constant, low dielectric loss.	High mechanical strength, good hardness.	Good electrical properties, close dimensional tolerances.	Fair mechanical strength. Good electrical properties.	A mixture of large alum...
Specific Gravity	—	—	2.6	2.7	2.6	2.7	2.1	2.1	2.1	2.0	4.0	4.0	2.8	2.8	2.3
Density	lbs./in.³	—	.094	.098	.094	.098	.076	.076	.076	.072	.144	.144	.102	.102	.085
Volume	in.³/lb.	—	10.65	10.26	10.65	10.26	13.20	13.20	13.20	13.85	6.93	6.93	9.76	9.76	11.7
Water Absorption	%	D116-39	.08-.00	.05-.00	1.0-.00	.08-.00	8.0-5.0	5.0-1.0	15.0-10.0	18.0-14.0	.05-.00	.00	1.5	1.0	2.5
Chemical Resistance		—	At room temperature resistant to all alkalies and acids (excepting hydrofluoric acid). For special problems consult American Lava Corporation.												
Color		—	White*1	Cream	White*2	White	Yellow-Tan	Grey-Brown*3	White	Light Brown	Tan	Tan	Light Brown	Brown	Fi
Softening Temperature	°C. °F.	C24-35	1 450 2 642	1 440 2 624	1 445 2 633	1 400 2 552	1 410 2 570	1 430 2 606	1 650 3 002	1 625 2 957	1 650 3 002	1 650 3 002	1 465 2 669	1 475 2 687	
Resistance to Heat Safe limit for constant (emp.)	°C. °F.	—	1 000 1 832	1 000 1 832	1 000 1 832	1 000 1 832	1 250 2 282	1 250 2 282	1 350 2 462	1 300 2 372	1 000 1 832	1 000 1 832	1 200 2 192	1 200 2 192	
Hardness	Mohs' Scale Talc = 1 Diamond = 10	—	7.5	7.5	7.5	7.5	7	7	6	6	8	8	6	6	
Linear Coefficient of Thermal Expansion 20-100° C.	per °C.	—	6.9x10⁻⁶	6.3x10⁻⁶	7.7x10⁻⁶	7.3x10⁻⁶	1.5x10⁻⁶	1.3x10⁻⁶	3.5x10⁻⁶	8.0x10⁻⁶	7.1x10⁻⁶	7.3x10⁻⁶	8.3x10⁻⁶	8.9x10⁻⁶	2.9x
Linear Coefficient of Thermal Expansion 20-600° C.	per °C.	—	8.7x10⁻⁶	7.8x10⁻⁶	10.4x10⁻⁶	9.2x10⁻⁶	2.5x10⁻⁶	2.8x10⁻⁶	4.9x10⁻⁶	9.8x10⁻⁶	8.6x10⁻⁶	8.7x10⁻⁶	10.5x10⁻⁶	10.4x10⁻⁶	3.4x
Tensile Strength	lbs./in.²	D116-39	8 500	10 000	8 500	7 500	1 500	3 500	2 000	2 500	7 500	7 500	2 000	2 000	2
Compressive Strength	lbs./in.²	D116-39	75 000	85 000	75 000	65 000	30 000	40 000	10 000	25 000	80 000	80 000	20 000	30 000	20
Modulus of Rupture	lbs./in.²	D116-39	20 000	22 000	20 000	18 000	4 000	8 000	6 000	8 000	20 000	20 000	8 000	9 000	9
Resistance to Impact	Charpy ft. lbs./in.²	D256-38	1.8	2.1	1.8	2.0	0.9	0.9	0.9	0.8	2.4	2.4	1.3	1.3	1
Thermal Conductivity (approx. values)	cal./sec./cm. per °C.	—	.006	.006	.006	.006	.003	.003	.003	.005	—	—	.005	.005	.00
Dielectric Strength. (@ 60 cycles) Test discs ¼" thick	Volts/mil.	D116-39	225	240	210	240	—	—	—	—	100	100	< 100	< 100	
Volume Resistivity Variable Temperatures 25° C 77° F	Ohms per Centimeter Cube	—	> 10¹⁴	> 10¹⁴	> 10¹⁴	> 10¹⁴	> 10¹⁴	> 10¹⁴	> 10¹²	> 10¹⁴	> 10¹²	> 10¹²	> 10¹⁴	> 10¹⁴	>
Volume Resistivity Variable Temperatures 100° C 212° F			2.1x10¹²	1x10¹³	8.1x10¹²	> 10¹⁴	4.0x10¹²	6.1x10¹²	1.2x10¹¹	> 10¹⁴	9.8x10¹¹	9.8x10¹¹	—	—	3.2
Volume Resistivity Variable Temperatures 300° C 572° F			6.0x10⁷	1.8x10⁹	2.5x10¹⁰	1.0x10¹²	4.8x10⁹	8.2x10⁸	7.8x10⁷	1.8x10¹¹	1.0x10⁹	1.0x10⁹	1.4x10¹⁰	5.7x10¹⁰	3.2
Volume Resistivity Variable Temperatures 500° C 932° F			3.2x10⁵	9.0x10⁶	8.8x10⁷	3.5x10¹⁰	2.0x10⁷	4.8x10⁶	7.3x10⁵	9.5x10⁸	1.7x10⁸	1.7x10⁸	1.7x10⁷	2.6x10⁸	1.7
Volume Resistivity Variable Temperatures 700° C 1 292° F			2.3x10⁴	5.0x10⁵	4.2x10⁶	4.8x10⁸	1.5x10⁶	3.2x10⁵	5.3x10⁴	4.1x10⁷	2.5x10⁴	2.5x10⁴	1.5x10⁶	1.3x10⁷	1.1
Volume Resistivity Variable Temperatures 900° C 1 652° F			< 10⁴	7.0x10⁴	6.8x10⁵	2.5x10⁷	2.2x10⁵	7.0x10⁴	1.0x10⁴	5.0x10⁶	<1x10⁴	<1x10⁴	2.6x10⁵	1.8x10⁶	2.0
Softening Point *4	°C. °F.	—	440 824	640 1 184	840 1 544	> 1 000 > 1 832	720 1 328	600 1 112	480 896	> 1 000 > 1 832	520 968	520 968	740 1 364	> 1 000 > 1 832	53 98
Dielectric Constant 60 Cycles	—	D150-39T and U.S. Navy Spec. RE 13A-317-F and U.S. Army Spec. 71-229-D	6.5	6.3	6.3	—	—	—	—	—	—	—	—	—	
Dielectric Constant 1 000 K. C.			6.2	6.0	6.0	5.8	4.1	5.0	4.0	4.3	8.5	8.5	5.6	5.6	5.3
Dielectric Constant 10 M. C.			6.0	5.8	5.8	5.7	4.0	5.0	3.9	4.2	8.5	8.5	5.5	5.5	5.0
Power Factor 60 Cycles	%		.30	.14	.20	—	—	—	—	—	—	—	—	—	
Power Factor 1 000 K. C.			.20	.08	.12	.02	.40	.40	.40	.02	.08	.08	.30	.45	1.0
Power Factor 10 M. C.			.18	.06	.10	.01	.30	.30	.30	.01	.06	.06	.25	.40	.9
Power Factor 60 Cycles	%		1.95	.88	1.26	—	—	—	—	—	—	—	—	—	
Power Factor 1 000 K. C.			1.24	.48	.72	.13	1.64	2.00	1.60	.09	—	—	1.48	2.52	5.3
Power Factor 10 M. C.			1.08	.35	.58	.06	1.20	1.50	1.17	.04	—	—	1.37	2.26	4.7
Capacity Change Per °C. between 20-80° C.	—	—	+1.6x10⁻⁴	+1.4x10⁻⁴	+1.6x10⁻⁴	+1.2x10⁻⁴	—	—	—	+1.0x10⁻⁴	−6.8x10⁻⁴	−6.8x10⁻⁴	—	—	—

*1 Can also be obtained in brown (AlSiMag 207) and in grey (AlSiMag 206).
*2 Can also be obtained in brown (AlSiMag 210) and in grey (AlSiMag 209).
*3 Can also be obtained in white-grey (AlSiMag 178).
*4 Te-value is the temperature at which one centimeter cube has a resistance of one Megohm.

AlSiMag
Trade Mark Reg. U. S. Pat. Off.
FROM CERAMIC HEADQUARTERS
AMERICAN LAVA CORPORATION • CHATTANOOGA • TENNESSEE
Full Size Chart Free at Your